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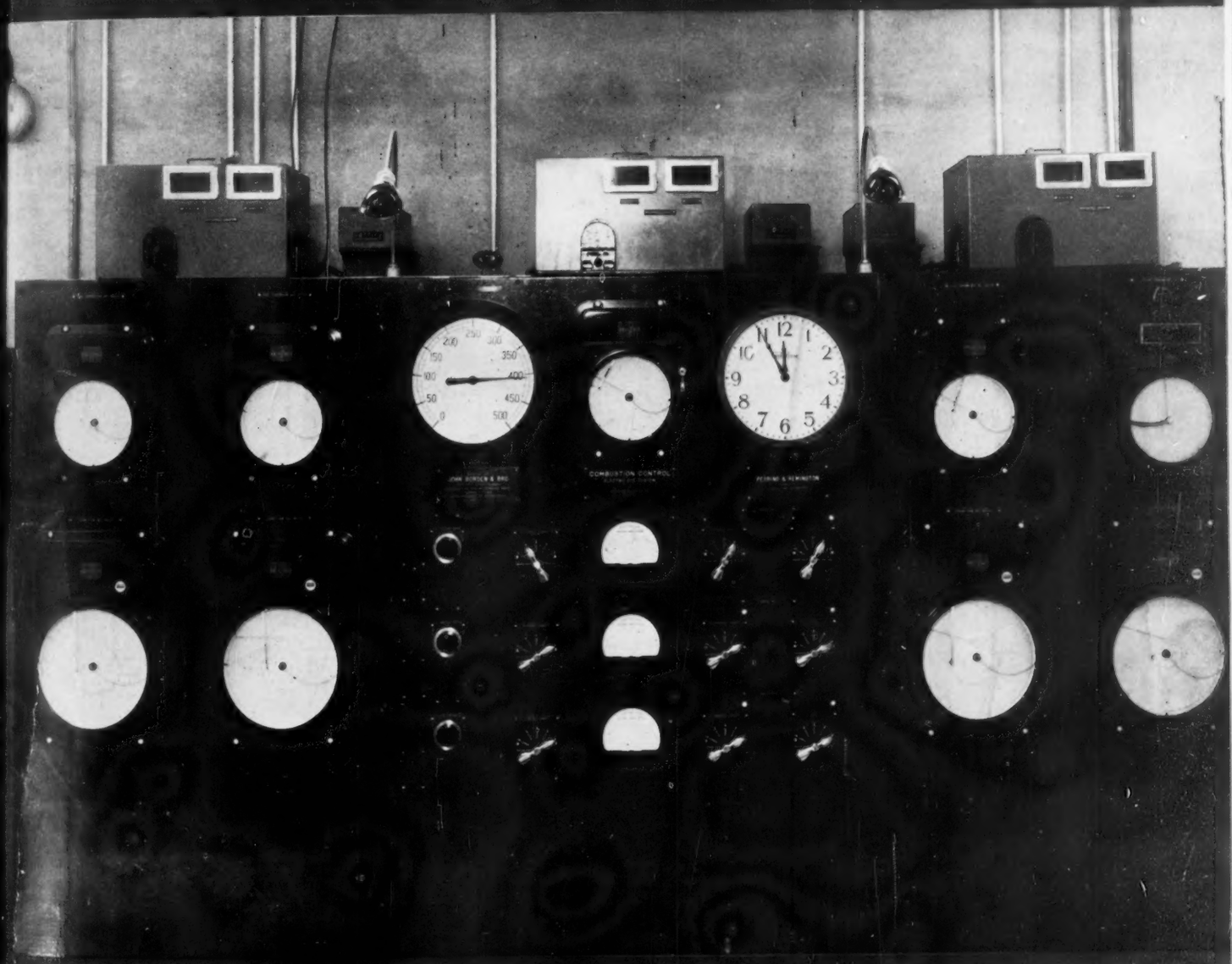

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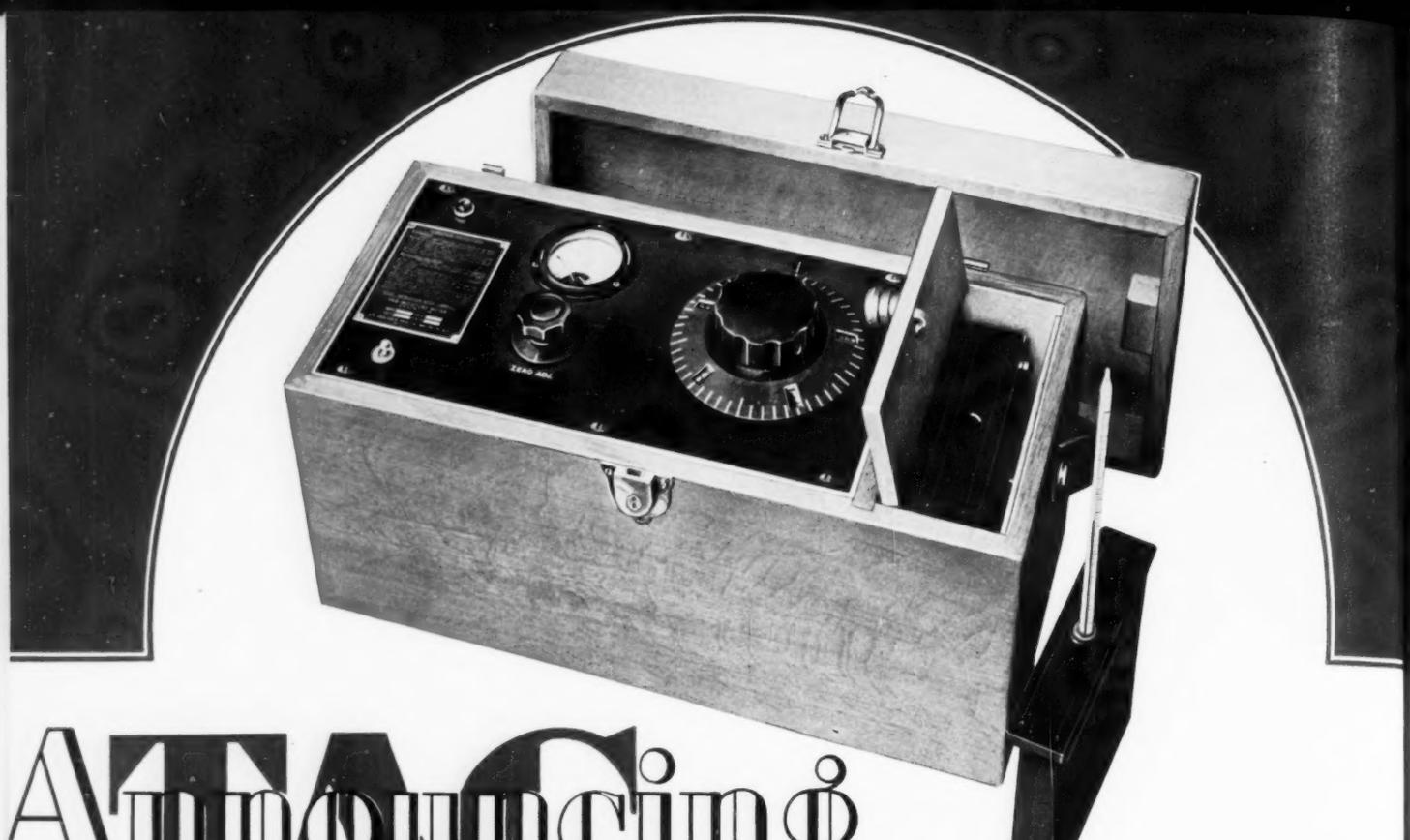


Announcing TAG DIELECTRIC TYPE MOISTURE METER

This, the latest addition to the well-known family of Moisture Meters manufactured by TAGliabue, opens up a wide field of application to such products as powders, granular materials, soaps, dehydrated foodstuffs, liquids, sheet materials, etc., many of which are not mechanically suitable for test with electrical conductance measuring moisture meters.

If you manufacture or use materials whose moisture content must be measured, this may be the instrument you need to improve your product or increase your production.

The new TAG Dielectric Type Moisture Meter is designed for the precise measurement of the dielectric properties of a test sample. Its extreme sensitivity is based on the fact that, while the dielectric value of most common substances is less than 10, that of water is about 80; slight changes in moisture content, therefore, have marked effect on the dielectric properties of these substances.

OTHER TAG MOISTURE METERS

TAG-Heppenstall Moisture Meter for Lumber
3000 now in use throughout the woodworking industries. Described in Bulletin No. 1213-I.
TAG-Heppenstall Moisture Meter for Grain
The official method of the United States Department of Agriculture. Bulletin No. 1199-I.
TAG-Heppenstall Moisture Meter for Tobacco
In use in the laboratories and factories of all leading Tobacco Manufacturers. Bulletin No. 1083-I.

C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.

TAG

Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

To Help Eliminate a Metering Bottleneck

WAR EFFORT conditions are creating an increasing need for the reliable metering of increasing quantities of an increasing number of different liquids and gases. Hence an increasing demand for an increasing diversity of "positive" meters or "quantity" meters.

At the same time, shortages limit (and in some cases are said to halt) the production of certain varieties of meters—even of certain types, or of certain makes.

As usual, American ingenuity and resourcefulness are licking this nation-wide problem—but perhaps too slowly. One solution of this problem which is being applied too slowly is to use another meter—not an inferior meter but one that will meter the particular liquid or gas just as reliably and with as little need for inspection and maintenance work.

The reason this solution is being applied too slowly is that many busy engineers, purchasing agents and others faced with this serious problem have no means of knowing what other meter to "substitute" in the specifications. The word "substitute" is usually the first one that comes to mind in such cases. The truth is that in most such cases there is a better meter, whose existence is not known in the office where the specifications originate. Back of this reason is another: the bewildering variety of positive meters. But this rich variety would provide an immediate solution of the problem . . . if it were widely known. The only fairly-detailed picture of this rich variety is the one which appeared in *Instruments* in December 1932. It consisted of a table representing the first attempt at a comprehensive and rational classification; and of explanatory text. Wide knowledge of this picture will help do away with the meter bottleneck. To this picture, our Information Department has been referring inquirers—advising them to look it up in technical libraries where files of *Instruments* are deposited. The need is so acute and so widespread, however, that the table (slightly revised) is published here and permission to reproduce it is hereby given to anyone serving the War Effort and reproducing it as a direct contribution to the War Effort. The explanatory text was a "chapter" (really a book) which ran serially in *Instruments* from Nov. 1932 to Nov. 1933. Most of this text consists of discussions of the numerous types and we frankly admit that busy engineers and specification writers need not wade through it unless they have a supply of headache powders.

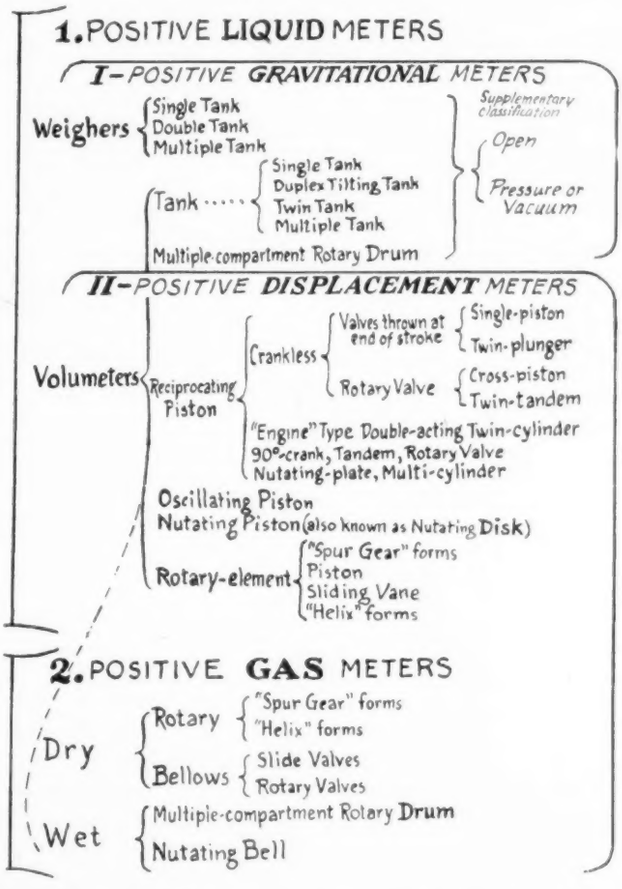
Some passages here and there are directly useful today, however, because they consist of fundamental discussions, because these fundamental discussions are as up-to-date as the day they were written and because they do not appear in any other reference work available today.* Therefore it is timely to reprint some of these passages:—

[From Nov. 1932 instalment]

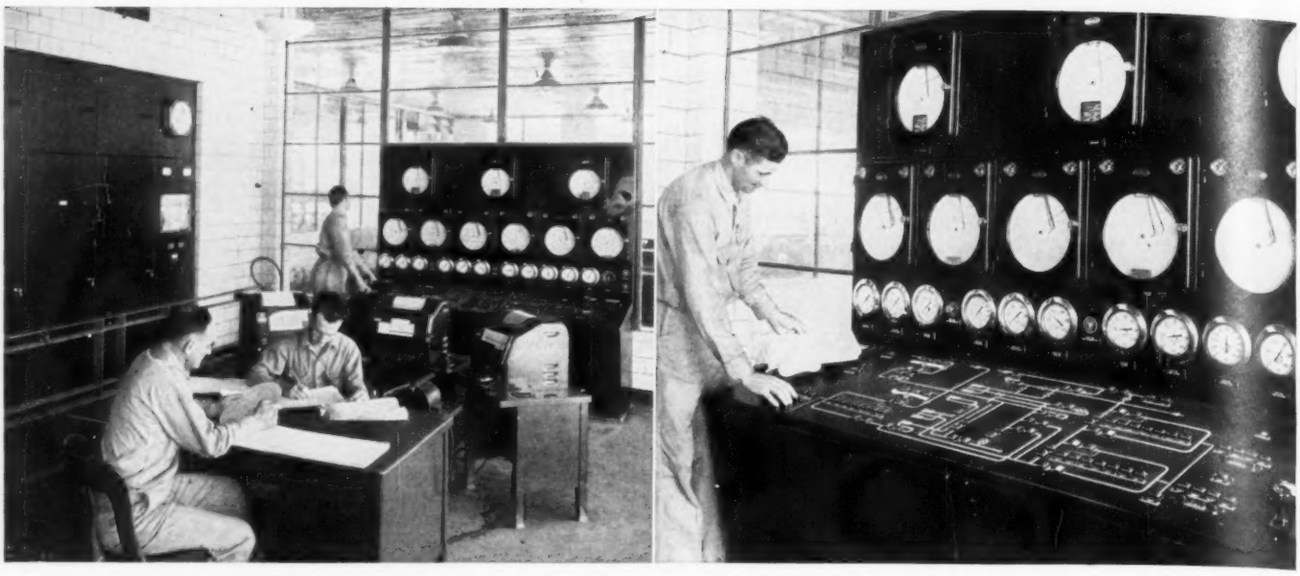
In 1922 the A.S.M.E. Fluid Meter Committee, representing not only a large segment of the engineering profession but various industries, the Bureau of Standards, etc., laid down in its Report a definition of positive meters which specified that "no fluid can pass through such a meter without actuating the primary device." [*Note* — The term "positive" is no longer used in the fourth (1937) edition of the Report but the influence of the earlier editions is still felt.] Now, in formulating the elements of Instrumentation, one does well to follow some recognized authority when treating any particular field of measurement. In the field of fluid metering now being dealt with, the A.S.M.E.'s maturely considered terminology and broad principles of classification of all fluid meters are the ones which we have chosen to follow. It so happens however that this very lack of ambiguity in the Report has created a rather paradoxical situation among engineers concerned with specifying, using or manufacturing quantity meters, because of the practical impossibility of making truly "positive" commercial meters of certain types that are in demand by reason of their convenience, simplicity and low cost.

(Continued on page 324)

CHAPTER XXIII, BEHAR'S MANUAL *of* INSTRUMENTATION
TABLE 23-1 - CLASSIFICATION *of* POSITIVE FLUID METERS



*Better treatments of these questions will no doubt be included in the A.S.M.E. Fluid Meter Committee's report on Quantity Meters (now being prepared) which will be the "bible" on that subject, just as Part I of the report is the "bible" on rate-of-flow meters.

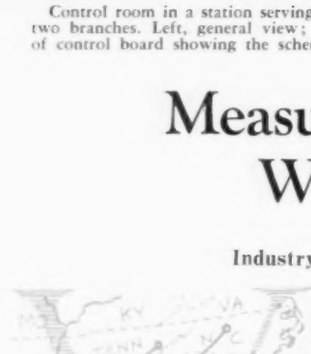


Control room in a station serving main line and two branches. Left, general view; right, close-up of control board showing the schematic pipe layout of station with its instruments. Board reveals flow rates, pressures at critical points, motor loads, temperatures of motor and pump parts. Lights indicate valve positions. Lights and control switches are arranged in appropriate positions in miniature layout of station piping.

Measurement and Control Features of World's Outstanding Pipe Line

By M. A. HYDE

Industry Engineer, Petroleum & Chemical Section, Westinghouse Elec. & Mfg. Co.



ITAL link in the nation's wartime transportation system, the world's largest pipe line for refined petroleum products has been placed in service. This 1261-mile line of the Plantation Pipe Line, from Baton Rouge, La., to Greensboro, N. C., established several new records. The first full-length delivery through the line was made in the incredibly short time of 180 days after the first trench was dug. The thirty-nine pumps in the sixteen stations are driven by explosion-resisting induction motors, some of them the largest of their type ever built. . . .

OPERATED LIKE A FREIGHT TRAIN

Operation of a pipe line might seem to consist of the simple process of putting the product into one end of the line, operating the pumps, and drawing it off at the other end. Actually, eight different products—several grades of gasoline, kerosene, diesel fuel, etc.—must be dispatched through the pipe line much as railroad trains are dispatched. Receipt of products at Baton Rouge is scheduled weeks in advance, and the scheduling of shipments and deliveries over the line is worked out according to carefully prepared plans.

Many times, all eight products are in the line at once. Deliveries of these products must be made at as many as seventeen different points, and some of these points require separate shipments to three different marketing companies. Deliveries may be at one point at a time, or multiple deliveries may be made simultaneously at several points on the system.

Consider, too, that this system is not a single straight, uniform pipe line, but consists of a short section of four parallel 12″ lines to a storage tank farm and the initial station of the pipeline proper; a 12″ section of main line to a mid-point at Bremen, Georgia, thence a section of 10″ main line to Greensboro; also, four smaller branch lines, 8″ and 4″, one of which, in turn, is branched.

This complex and ever-changing dispatching function for the entire line is centralized in a dispatcher's office in Atlanta. All pumping stations and delivery points are connected to the dispatcher's office by a teletype system providing continuous recorded inter-communication. Delivery terminal take-offs are measured with extreme accuracy by positive-displacement meters. From the dispatcher's office are issued all orders governing the routine operations of the line, including starting and stopping of stations and units within the stations.

One of the critical features of multi-product line operation is the prevention of intermixture of different successive shipments (called "tenders") as they move end-to-end through the line and the pumping stations. To accomplish this it is necessary to maintain velocity in the line higher than a critical minimum value. At any lower velocities a phenomenon akin to laminar flow takes place, with greatly increased intermixing. Obviously this places an unusual premium upon reliable operation of pumping equipment.

At any station, the time of transition from one tender to the next can be predetermined within a few minutes from the data available in the dispatcher's office. Exact determination at the station itself is by change in the color of successive differently-colored tenders, by the passage of a small quantity of dye interposed between the two tenders, or by a continuous auto graphic record of specific gravity of the tenders, obtained by a highly sensitive gravitometer. This instrument consists essentially of a spherical weighing chamber, of exactly known volume, through which is diverted continuously a small stream from the pipe line. The weight of this known volume, corrected for temperature, is recorded in terms of specific gravity on a clock-driven chart. This ultra-sensitive gravitometer is able to show differences in specific gravity as little as 0.002.

This article is based, in part, on a paper "Electrical Features of Design and Operation of the Plantation Pipe Line," in co-authorship with Mr. H. B. Britton, Chief Engineer, Plantation Pipe Line, presented before the American Institute of Electrical Engineers, Chicago, June 26, 1942. The statements made regarding locations, capacities, pressures, and horsepowers, both for present operation and future installation possibilities, do not necessarily represent actual conditions, but do indicate the general principles involved.

line as initially equipped can deliver 60,000 barrels of gasoline daily through the 12″ section, and 42,000 barrels daily through the 10″ section.

The maximum operating pressure is approx. 900 lbs./in.^{2} in the 12″ section and 975 lbs./in.^{2} in the remaining sections. If the minimum allowable suction pressure at each station is established as, say, 40 lbs./in.^{2}, then with a maximum allowable station discharge pressure of 900 lbs./in.^{2}, the pressure increment introduced into the line at any station is 860 lbs./in.^{2}, plus the pressure loss through the station piping. The stations are so spaced, then, that the pressure drop between stations resulting from fluid friction at rated flow, plus the static pressure differential, totals approx. 860 lbs./in.^{2}. . . .

With the station location determined solely by the hydraulics of the line and, therefore, without regard to existing power facilities, it was necessary to consider carefully the method of starting the units, from the standpoint of voltage conditions on the electric service. . . .

Non-hazardous atmospheric conditions are maintained in all parts of each pumping-station building, except the pump room and piping platform. No direct passageway connects the operating portion of the building and the pump room. It is necessary to pass through outside entrances in going from one to the other. The atmosphere in the operating section is maintained safe by drawing outside air into the building at the end farthest from the pump room, and maintaining it at a slight pressure above the outside air and above the atmosphere in the pump room. [*Editor's note* —The glass walls seen in the control-room photographs are vapor-tight] Any air seepage through the wall separating the operation section from the pump room or piping platform will be toward the pump room instead of from it. . . .

If the control room atmosphere should become hazardous because of an equipment failure, the entire station can be safely shut down by pushing an emergency button. . . .

CONTROL SYSTEM PROVIDES AUTOMATIC SEQUENCE OF OPERATIONS

Starting and normal stopping of the stations and of units within each station are controlled by the station attendant. Protective shutdown of units and stations is instituted automatically when conditions arise that exceed predetermined limits of safe operation, whereupon an audible signal is given, supplemented by light indication of the specific protective function that caused shutdown.

The duties of the attendant incident to the starting and stopping of main line units are simplified by providing automatic operation in one complete sequence for the valves, motor control, and pressure devices concerned. The operator, thus relieved from performing a routine of manual operations at different points in the station, can devote his attention to the overall process and to the results obtained.

For continuous operation of the line it is necessary, of course, to maintain pressure conditions within the limits predetermined for protective shutdown, and this is accomplished by automatic means.

The control system developed to meet these requirements embodies the coördinated application of pressure, temperature, and electrical measurement and control devices.

Each pump unit normally is controlled entirely from an individual "start-stop" pushbutton, the control system providing the proper sequence of starting and shutdown operations.

Considering a typical two-unit booster station, this control system provides automatic means for:

1—Venting the pump casings during shutdown to prevent building up of pressure within them by leakage past suction or discharge valves.

2—Permitting the starting of a unit only upon existence of a predetermined minimum suction pressure.

3—Operating in correct sequence a motor-driven suction valve and a motor-driven discharge valve for each unit.

4—Venting vapor from the pump casing, and circulating liquid through the pump, during starting.

5—Adjusting the station capacity to the line throughout while the station is on the line.

6—Limiting the minimum value of station suction pressure to a value safe for pump operation.

7—Limiting the maximum value of the station discharge pressure to a value safe from the standpoint of pipe line stress.

8—Safety shut-down, sounding the station alarm and lighting an individual indicating light, in case of excessive duration of high motor starting current, high temperatures at motor and pump bearings, pump glands and pump casing, low or high pump suction pressure, low or high station discharge pressure.

9—Alarm and individual light indication for high motor winding temperature, high sump tank level, low station air supply pressure, and low air supply pressure to hydraulic controllers.

10—Station Pressure Control. The regulation of station pressure is accomplished by air-operated instruments of such a nature that the station suction and discharge pressures can be automatically maintained at any pre-determined value. Normally, each control valve is commanded by these instruments automatically, but it is equipped for manual operation in the event of air failure or interruption of electric service at the stations. All the stations operating in a continuous section of line are affected by any change in flow rate that may occur. There are many changes in flow rates throughout the entire system. These are occasioned by the existence of the large number of delivery points or terminals, which may be utilized for multiple deliveries or for single full-line capacity deliveries. The station pressure controls are so designed as to immediately adjust each station to these varying flow conditions, thereby maintaining uninterrupted operation.

The automatic shutdown features are coördinated with the regulating equipment in order to permit operation of the control system over its full range and only prevent operation of one or two units in the station in case the pressures exceed pre-established limits.

STATION CONTROL DESK AND INSTRUMENT BOARD

The control for each station centers in a control desk immediately in front of the instrument board. Nearby are the attendant's working desk, teletype, and telephone.

The instrument panel mounts a flowmeter for indicating and recording the rate of flow at or by the station, also the two pressure controllers and six gauges indicating pressures at critical points.

On the control desk are mounted the red indicating lights identifying the functioning of each of the protective shutdown and alarm switches. Amber and green indicating lights show respectively the open and closed positions of the motor-operated suction and discharge valves, and the relative positions of the principal manually-operated valves in the station piping.

To clarify the function of each device, the desk top bears a schematic layout of the principal piping for the particular station. In this piping diagram are mounted in appropriate position the pushbuttons, indicating lights, and also ammeters showing current in each motor.

Similarly mounted are temperature indicators on which can be read the temperatures of thermocouples in motor windings, in motor bearings, as well as in pump bearings, glands and casings.

The accompanying illustration shows how conveniently the control desk and instrument board serves as the focal point for indication of condition and control of all principal station functions.

About six miles of control wiring, considered as single-conductor, is installed in a typical two-unit station; about twice this amount in one of the stations serving the main line and two branch lines. Approximately sixty miles of control wire is used in the initial station, including the tankage control and indication circuits.

System Frequency and Its Control*

By HENRY A. DRYAR

Chief Load Dispatcher, Philadelphia Electric Co., Philadelphia, Pa.

THE ELECTRIC POWER SYSTEM is comprised of generators, transformers, motors and all devices used in the generation, transmission, distribution and utilization of electrical energy. The frequency of the electric power system is the electrical speed at which it operates.

The operation of the electric power system at an electrical speed that deviates from the standard frequency is attended by a number of abnormal conditions including the following:

Low frequency reduces industrial production.

Abrupt and pronounced changes in frequency may cause damage or spoilage of products.

Errors in the frequency cause errors in electrical time.

Damage to Products

Extremely abrupt changes in frequency may result in damage to textile production from breaking of threads and the uneven dyeing of yarns and cloth and damage to the output of paper manufacture because of the breakage of paper. Damage to the products of other industries as, for instance, in the food baking plants, may occur also as a result of abnormal frequency affecting the speed of conveyors.

Such changes in frequency in former years occurred in normal operation. The inertia of the modern interconnected system is such that a speed change of this magnitude would mark a major disturbance.

Variations in the System Load

The term "system load" is defined as the combined simultaneous demand of all the customers of the electric utility company. As the connected load of the system or the total wattage rating of all electrical utilization devices which may be connected to the company service is three to four times the maximum combined demand, it is obvious that there must be continual and appreciable changes in the system load as equipment is connected to or removed from the sources of energy.

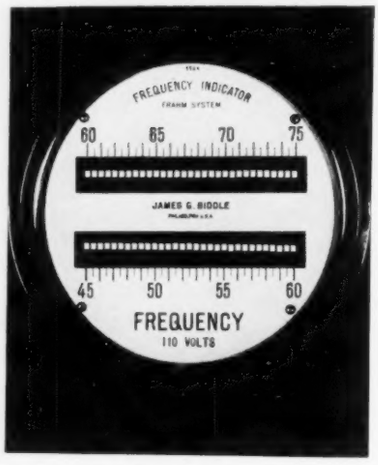


Fig. 1. Installation of a more recent type of vibrating-reed frequency meter.

These changes in customer demand due to the turning on or off of lights; the starting or stopping of motor-driven equipment, refrigerators, elevators, rolling mills, etc., the operation of trolley cars and trains, produce a fringe on the load curve that causes speed variations.

The Isolated Generating Station

The generating system of the Philadelphia Electric Company prior to 1915 was comprised of a number of isolated generating stations none of which operated in parallel with the other. The largest in capacity had a rating of 64,000 kw., and the smallest, 1000 kw. The sum of the capacities of these generating stations was 107,000 kw.

If we consider the operation of each generating station separately, it is obvious that the variations or the fringe of the load of the 1,000 kw. plant was a much greater percentage of its load than was the fringe of the load of the 64,000 kw. plant in relation to its load.

This is a result of the increased diversity in these load changes as the system load increases, making the load fringe a smaller percentage of the customer combined demand.

The Isolated System

In 1916, continued parallel operation of two generating stations was first effected on the Philadelphia Electric Company system. The two generating stations involved in this operation were the Schuylkill Station at 27th and Christian Streets, Philadelphia, and the Beacon Plant in Chester.

As the system generating capacity operating in parallel increased with the growth in system load, a continued narrowing of the frequency band was observed. This was an effect not only of the greater diversity in the load changes on the fringe of the curve but, to a far greater degree, of the greatly increased inertia of the system and more frequent response of turbine governors.

First Measurement of Frequency

During the many years prior to 1924, the instantaneous frequency measuring device in use in the power plants was the vibrating reed frequency meter.

With this instrument as then available it was difficult to determine the actual frequency with any degree of accuracy. The frequency might be one percent high or one percent low. It could be said that the standard for calibration was the Production Manager of the industrial plant. When he 'phoned that he was down one percent in his output, the system frequency was raised and a new mark for actual 60 cycles was observed.

Advent of Electrical Time

In 1920, a Warren Master Clock was provided on the system of the Philadelphia Electric Company. This device, which compares the time of an accurate mechanical clock and that of a synchronous motor-driven clock operated from the system potential, indicates an average system frequency of 60 cycles when the two clock hands are rotating together.

The development of the master clock was an outgrowth of the difficulty in accurately reading the reed meters. The electric clock which the inventor had hoped to make a commercial success had consistently lost an average of about ten minutes each day. Finally, he found the cause. The frequency of the electrical supply was low.

With this Master Clock it has been possible for the operating companies to provide service of a satisfactory average frequency. Because this type of service was provided, it has been possible for the inventor to market his device.

Leeds & Northrup Frequency Recorder

In 1924, the Leeds & Northrup Company of Philadelphia developed an accurate device for measuring the system frequency. This enabled the operating companies to supply service having greatly improved instantaneous frequency.

Each refinement in the regulation of the system frequency was serving to improve the economy of each generating station by the reduction of the appreciable changes in station output which had characterized operations in the past.

System Generating Capacities

During the years of operation prior to the first major interconnection made by the Philadelphia Electric Company, the growth of system load and capacities was very great. As the system load and capacities in rotating equipment—including that of customers and company—increased, the frequency band became narrower and its regulation at this

*Presented before the Instruments and Measurements Discussion group of the Philadelphia Section of the American Institute of Electrical Engineers.

time presented but one problem, that of the burden of the regulating station.

The Regulating Station

Although, as time went on, the fringe of the load became a smaller percentage of the total demand of the customers of the company, the actual change in the load was greater than it had been.

As more efficient generating capacities were provided, these were loaded to their maximum rating with the result that the only generating capacities available for frequency regulation were in the older stations, where reserve equipment was operating as coverage for the possible loss of the largest unit.

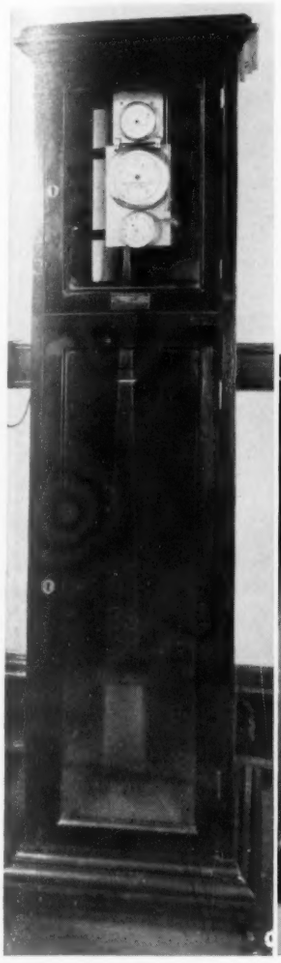


Fig. 2. Installation of Warren Master Clock in Load Dispatcher's Office (1920).

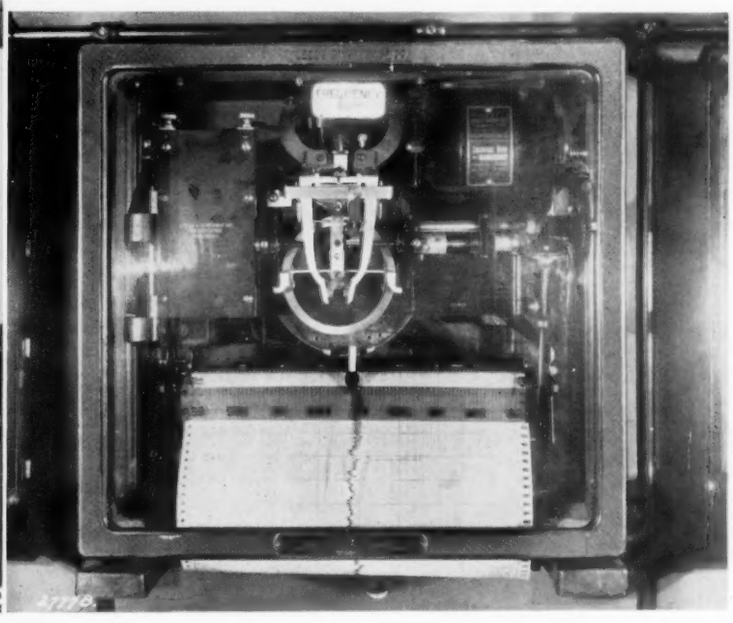


Fig. 3. Installation of Leeds & Northrup frequency recorder (1924).

The burden of regulating the system was then placed on this one station and as a result it was frequently subjected to output changes of 30% or approximately 50,000 kw., and because of this there was an appreciable loss in economy.

A Major Interconnection

In 1928, Conowingo hydro plant of 252 Mw. capacity was placed in operation and the 220 kv. interconnection was established, bringing conditions that might tend to aggravate the general problem of frequency regulation.

In the case of Conowingo, operation of the hydro units at maximum rating placed the entire burden of regulation on the steam generating system and as the efficient stations are loaded to full rating this burden is transferred to one or two steam generating stations. Under these circumstances, there may be little, if any, response of turbine governors to speed changes.

In the case of the interconnection, the paralleling of two systems increasing the inertia of the system to change, effected a narrowing of the frequency band. With the growth of the interconnection, however, the amount of spinning reserve capacity was considerably reduced, thus further diminishing the generating capacity available for regulation.

Extension of Interconnected Systems

With the growth of the interconnection, we find the greater inertia of the group of systems, the greater tendency to response of the larger number of turbine governors and the increased diversity in the load changes, each serving to improve the regulation of the frequency.

Although the frequency chart in general was improved and the burden on any one station was not excessive, nevertheless there were occurrences almost daily that occasioned abnormal changes in station output.

As the systems interconnected increased in number, holding the tie lines between systems to the scheduled loading became a problem. These tie lines were at a distance from the frequency control center and from observation of their load changes.

Frequency Change A Guide to Load Variation

Because tie lines between systems are located at a distance from the frequency control center and their number makes their remote metering uneconomical, the Load Dispatcher must refer to the frequency meter deviations from standard speed for knowledge of changes in load. Usually, a drop in system speed indicates an increase in the load of some system of the interconnected group; a rise in system speed indicates a decrease of load.

If the load change occurs on a system that has the responsibility of correcting tie lines and this system fails to make the correction, the frequency control center will direct some station to correct the frequency and the tie line loading will be further upset. If the tie line loading is then corrected, there will occur a frequency error in the opposite direction. Small and immediate changes in loading to correct frequency errors or tie line departures from schedule to be followed by a check of tie line conditions before further corrections are made would eliminate much of the objectionable "see-sawing" of station output and frequency.

Correction of Electrical Time

The correction of errors in electrical time is made by maintaining the frequency above or below standard until the error is eliminated. If the electrical time, for instance, were two seconds slow, a station would be directed to increase its output 5,000 kw. This operation would raise the frequency approximately $\frac{1}{20}$ cycle. Maintaining the average frequency $\frac{1}{20}$ cycle high for 40 minutes would correct the two-second error in the electrical time.

Cycle Counters

The use of cycle counters in many kinds of laboratory tests may tend to influence the regulating practice to an appreciable degree. Where the test interval is extremely short it may call for high accuracy in the maintenance of instantaneous frequency. At the present time, the frequency is held usually within one-tenth cycle of standard. The degree of accuracy is thus within one-sixth of one percent.

Ordnance Production Gaging

By CAPTAIN RUSH A. BOWMAN

In charge of Pittsburgh Gage Laboratory, Ordnance Department, U. S. Army

CHAPTER III

OUTSIDE DIMENSIONS

Inspection of outside dimensions is accomplished by a smaller classification of gages than perhaps any other type of dimension. The reason is logically the fact that outside dimensions are most accessible. Three classifications only provide us with the necessary gages to measure almost any outside dimension. They are, namely: ring gages, snap gages, caliper type gages.

1. Ring Gages

American Gage Design Standard has set up the necessary specifications for the gage blanks from which plain ring gages are made. The specifications have been set up in order to gain the necessary stability for ring gages inasmuch as if they are improperly made or if they are weak they are particularly vulnerable to distortion during the ordinary inspection operation. Ring gages (see Figs. 1 and 2) are used normally on well finished surfaces, that is to say, finished machine, round, lapped, etc., where tolerances of five to six thousandths of an inch on the finished product are necessary. Ring gages have the property, as plug gages, of inspecting an entire surface in one operation. That is, line contact or surface contact is maintained around the entire periphery of the part being gaged. In addition, ring gages provide a method for determining straightness in order that the relative position of adjacent cross sections maintain a constant center line. Conditions are frequently found in which tolerances are apparently reduced, that is, in order that a ring gage may pass a part such as a shaft, it is found that the complete tolerance may not be planned in manufacture inasmuch as any run-out or deflection of the center line will affect the inspection with the ring gage.

Ring gages, however, are usually a comparatively slow device for inspection, except for experienced personnel. In addition, when the "not go" is used they provide no means for determining an out of round condition much the same as a plug gage. Ring gages also wear rapidly due to the fact that surface or line contact is maintained rather than point contact and no good means has yet been determined for making a plain ring gage adjustable with any great degree of accuracy.

2. Snap Gages

Snap gages provide a rapid method for inspection of outside dimensions. Snap gages are classified into plate type, adjustable type, and built-up type. The plate type gage, as its name implies, is made from plate steel of a thickness ⅛ inch to ¼ inch or even more. Plate type gages are the most simple of gages for determinations of outside diameter and they provide a rapid means of inspection, but their

Fig. 1. A Ring Gage in Use. Checking the diameter of the bourrelet of a projectile. (U. S. Army photograph.)

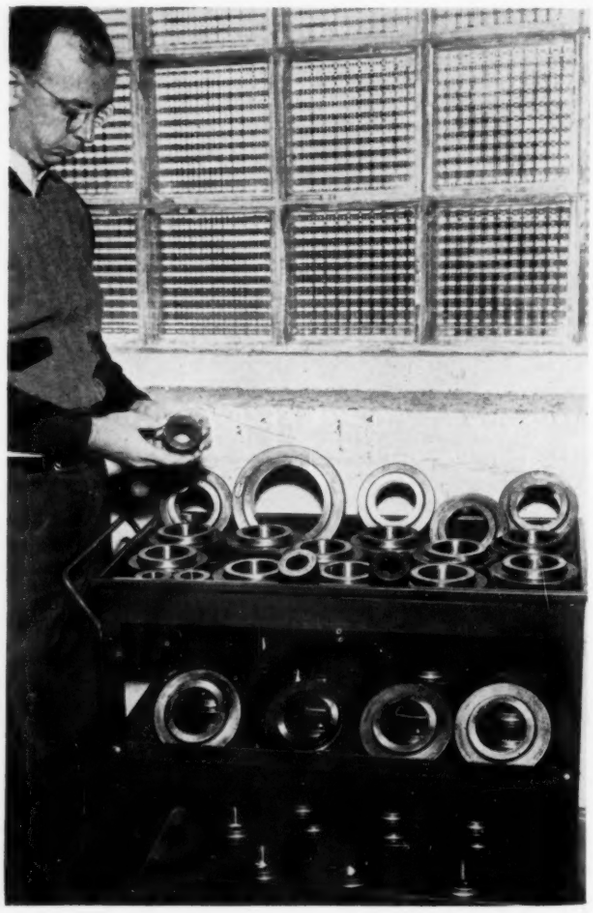


Fig. 2. An Assortment of Ring Gages for Artillery Ammunition. (U. S. Army photograph.)

Fig. 3. Adjustable Snap Gages. The stand provided enables the inspector to perform inspection without handling the gage, eliminating possible inaccuracies due to temperature changes and materially speeding inspection.

life in general is short. They are given easily to distortion in view of the fact that they are so thin. They are normally used for less accurate work. They are perhaps the least expensive of gages and are therefore not designed for reclaiming. They can be reclaimed only by chromium plating which is normally prohibitive based upon the original value of the gage.

Fig. 4. Showing Three Adjustable Snap Gages, one of which is being used to check the body diameter of a projectile. (U. S. Army photograph.)

Adjustable Type.—The specifications for adjustable type snap gages are also set up among the American Gage Design Standards due to their wide usage. Adjustable snap gages (see Figs. 3 and 4) are used for inspection of almost all tolerances a thousandth of an inch or more and provide a rapid means for inspection inasmuch as they are normally used as progressive gages—that is, the foremost anvils are set to "go" tolerances and the rear anvils to "not go" tolerances, enabling the inspector to check for both limits of component tolerances in one pass of the gage. Their life is long, inasmuch as they are adjustable and their life is limited only by the fineness of the fit between the anvil and the frame and of course the thickness of the anvil. When badly worn, adjustable snap gages must be lapped in when reset in order to maintain parallelism between the checking points.

Adjustable snap gages are frequently used as a supplement to a "go" ring gage to inspect the "not go" limit of a cylindrical component. When used in this capacity their

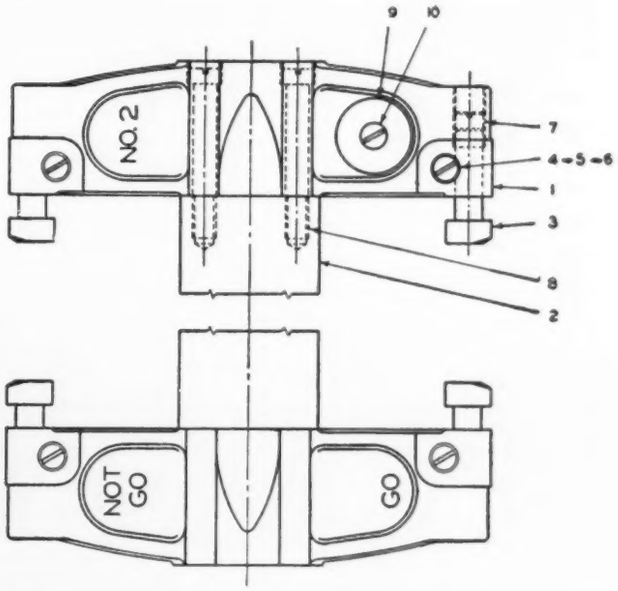


Fig. 5. American Gage Design Standard Adjustable length gage. Details of construction. (Reproduced from CS 8-41.)

1. Gage head
2. Spacing bar
3. Gaging button
4. Locking screw
5. Locking nut
6. Locking bushing
7. Adjusting screw
8. Gage head screw
9. Marking disk
10. Marking disk screw

purpose is to determine any out-of-round condition in the component. In such an application, of course, only one of the adjustable anvils is used—usually the foremost. Care must be used in the use of a snap gage because while American Gage Design standards are based upon strength in the frame these gages are still liable to distortion—especially where tolerances are small.

Another type of gage closely resembling the ordinary adjustable snap gage is the adjustable *length* gage (Fig. 5). As its name implies, it is meant to inspect overall lengths of component parts. Its applications, advantages, and disadvantages are much the same as the snap gage and standards have been set up by the American Gage Design Committee.

Built-up Type.—Built-up snap gages (see Fig. 6) compare in the inspection of flat surfaces with ring gages in the inspection of round surfaces. The surfaces on built-up snap gages are normally large and are designed for the determination of flatness and parallelism as well as actual size.

Having essentially a surface contact rather than a line contact wear on built-up snap gages is normally high. How-

Fig. 6. Built-up Snap Gage being used to inspect bullet cores. Also shown is another built-up snap gage; as well as a twin ring gage. (U. S. Army photograph.)

ever, they are readily reconditioned when they wear out of size by lapping the surface true and then grinding the spacer in order that the correct size may be gained.

Indicating Type.—This type (Fig. 7) is of increasing importance by reason of its ability to indicate the relative position of the size within component tolerance in order to maintain surveillance of machine tools. Being purely a

Fig. 7. Indicating Type Snap Gage shown gaging a cylindrical component. This gage is "mastered" with gage blocks or specially-built masters similar to component part and manufacture within Gage Tolerance Limits.

Fig. 8. Indicating Caliper Type Gage Being Used for Cylinder Head Thickness.

comparator, it requires more upkeep and care than ordinary gages, as explained in Chapter I.

3. Caliper Gages

Caliper type indicating gages provide also a rapid means for inspection. (See Fig. 8.) The caliper type gage is the oldest type of measuring device for outside dimensions. It is generally used for tolerances greater than five thousandths of an inch because of the inherent inaccuracies in any type caliper gage as described in Chapter II—its inherent characteristics are swinging measuring points in an arc and the fact that measuring points do not normally meet. When an indicator type caliper is used a master is normally used in connection with it and considerable surveillence is necessary in order to assure accuracy in inspection.

Automatic Gages

Of all new developments in gaging, the most important—especially with regard to outside dimensions—is automatic gaging. This will be the subject of a later chapter. At this

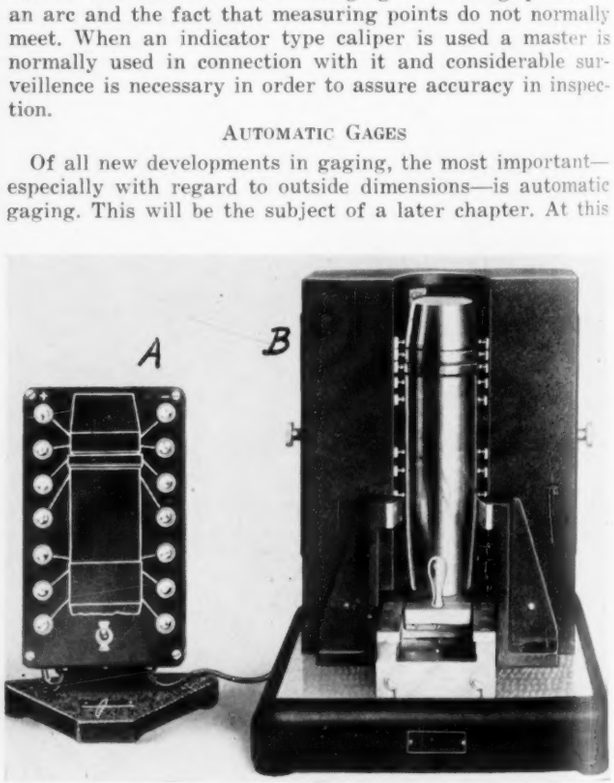


Fig. 9. Automatic multiple-dimension gaging device. Shell is introduced into gage proper *B*, as shown, and seven dimensions are simultaneously measured,. the "over" or "under" size dimensions being indicated by "plus" and "minus" lights on the "control panel" *A*.
NOTE—Automatic gages of various types are discussed in a later chapter.

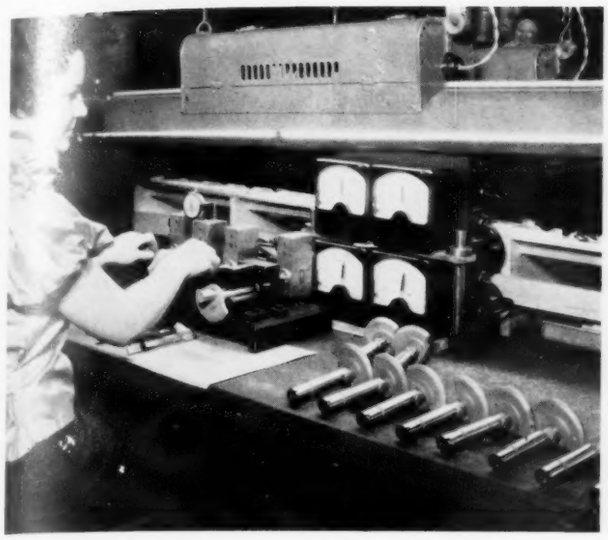


Fig. 10. Automatic multiple-dimension gaging device employing the "electric micrometer" principle.

point, however, two illustrations may be given: Fig. 9 shows a set-up which indicates by means of plus and minus lights and Fig. 10 shows a "comparator" type which indicates by means of pointer-and-scale instruments.

Inspection

While the gages for the inspection of outside dimensions are normally the most simple of all gages to design and use, the inspection of these gages entails some of the most difficult problems in gage inspection.

Ring Gages. The instruments used in the inspection of a ring gage will of course depend upon the accuracy which is to be maintained in the gage. Several types of inspection machines (see Figs. 11 to 14) have been designed for the inspection of inside diameters of ring gages with considerable success. These machines are, however, normally expensive and require extremely accurate setups. Ring gages may be inspected also with the use of gage blocks. When inspected in this manner, calibrated rolls are used. Gage blocks are built up to the desired diameter of the ring gage less the sum of the diameter of the rolls. The gage blocks may then be inserted between rolls within the ring and the large diameter found by feel. When used properly they provide a quite accurate means of inspecting for "bell-mouth"

Fig. 11. Inspecting a Ring Gage by means of an internal comparator graduated in ten-thousandths of an inch.

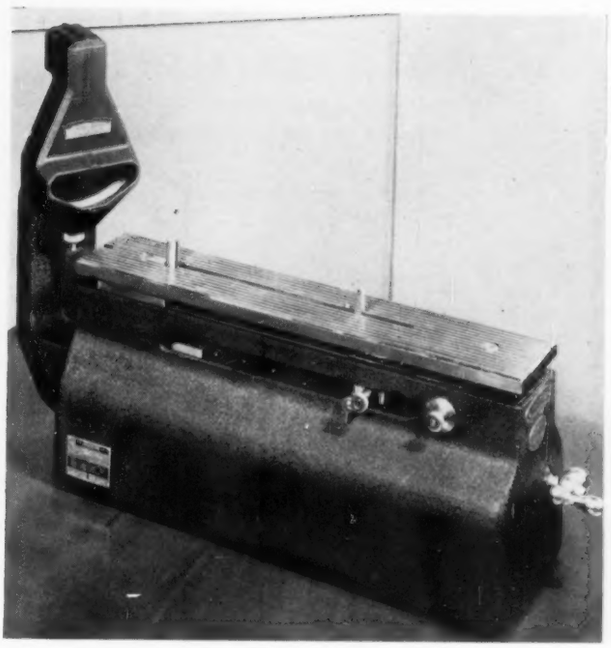


Fig. 12. Visual Internal Comparator for Inspection of Plain Ring Gages. The range is ⅝" to 12". The adjustable points are "mastered" to gage blocks and the size of the ring being inspected is compared with the master settings thus obtained. The instrument does not embody a pointer but employs a light-spot instead (like a mirror galvanometer).

by rocking. "Bell-mouth" is a condition experienced in almost every ring gage and arises from the fact that any lapping operation will be more effective at the edge of the opening than in the center. The "mouth" or edge of the opening will consequently be a slightly larger dimension than the center of the ring. For diameters of 0.250" or less, which cannot be measured successfully with gage

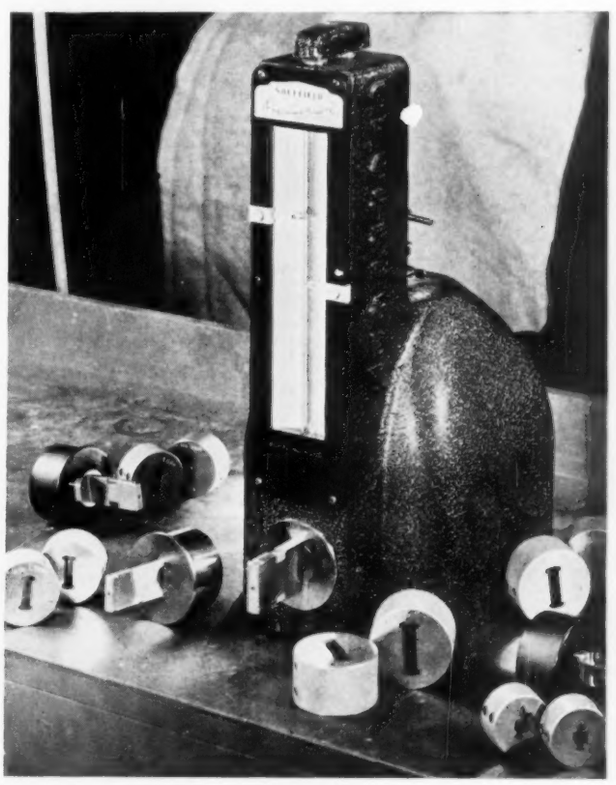


Fig. 13. Pneumatic Master Gage (inside-dimension type) being used for inspecting outside dimension gages of an unusual type made up for a special purpose.

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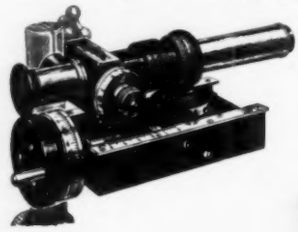

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Fig. 14. Internal Comparator and Measuring Machine for Checking Ring Gages. Note standard gage blocks (indicated by arrow) whereby the gaging fingers of the machine are set to the size with which the ring gage is to be compared. The indicating-instrument scale is graduated in hundred-thousandths of an inch. (U. S. Army photograph.)

blocks, a check plug is necessary. Conditions of "bell-mouth" may be determined by "bluing in" the plug with the ring. The "bluing-in" process consists of the application of ordinary artists' Prussian blue to one or the other part and then the insertion of the plug in the ring. When withdrawn, the surface contacted between the plug and ring is shown by the intensity of the blue which remains in the ring. Such check plugs must have a greater accuracy than is to be maintained on the ring itself and the size of the ring can only be estimated from the "play" or shake in the check plug.

A "limit plug"—a plug made to the largest size allowable for the ring—is then made; and when the ring has worn large enough to permit the entrance of the limit plug the ring is worn out of tolerance.

Snap Gages. Snap gages of all types, adjustable, built-up, and plate are inspected in much the same manner. The roll is also used in connection with the inspection of snap gages for the determination of parallelism between the anvils. The gage blocks are built to the desired size less the diameter of the roll. If possible, the gage block is then wrung to one anvil of the snap gage and the roll is rolled between the end of the blocks and the other anvil. This provides a line contact with the anvil and permits by means of feel, the determination of whether the anvils are parallel. This method may be used as a quantitative check on the amount of out-of-parallelism by determining the greatest and smallest point between the anvils. Considerable care should be taken in the handling of the roll because due to its lack of mass it will rapidly draw heat from the hand of the inspector and consequently cause an appreciable difference in its size.

Caliper gages of the indicating type, as explained above, are invariably set to some standard such as a master or gage blocks.

A Practical A-c. Bridge Construction

By CHARLES E. DIEHL
Master Mechanic, Utah Idaho Sugar Co., Spanish Fork, Utah

NEW instruments are now furnished on such high priority ratings that they are practically non-existent. Needing extended bridge facilities, several attempts to manufacture suitable types for our own use were made without great success until the one herein described was produced. This bridge has inherent characteristics such that we hope it may prove useful to others who may need a bridge for their own use but be unable to obtain any thing to fill the need.

The first point is one that is the most desirable for shop or laboratory construction. The ratios are exact and predetermined by its construction. *They require no calibration.* To anyone who has attempted bridge construction, this point will be startling. The other point is the fact that the voltage impressed on the bridge is variable in direct proportion to the ratios used. High voltage for high resistance and low voltage for low resistance to be measured. The ratios are such as are used in standard bridge practice.

In the diagram the two bridge arms are seen to be the secondary of a transformer. The two arms are wound as two symmetrical coils so constructed that turn resistances will vary as turn ratios vary. This is desirable but not entirely necessary as extremely small errors will occur if this is neglected to some extent. Turn ratios are mechanically recorded by a counter and must be exact.

In the commercial bridge circuit, an impressed voltage is divided by the ratio arms into more or less exact ratios, depending on calibration. The transformer secondary produces these ratios in exact relation without calibration. With two standards available, the bridge itself was used to produce the resistances for the "Y" arm. Subsequent checks against a good commercial Wheatstone bridge showed our values within the limits of the commercial instrument at the low ohm values and much more sensitive at the higher readings due to the increased voltages impressed.

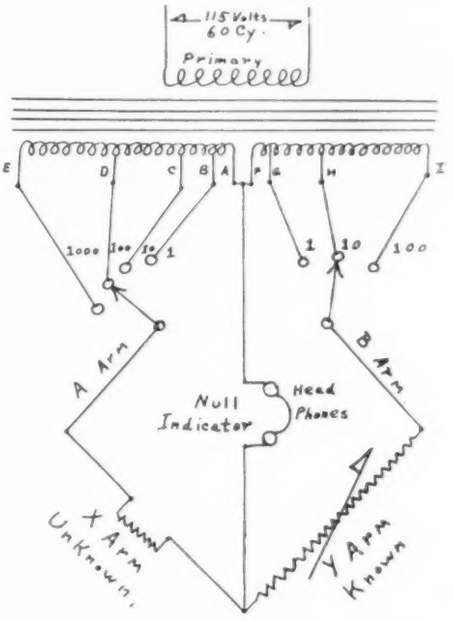
Transformer details are as follows:

Core of regular commercial silicon iron. Shell type, cross section $1'' \times 1\frac{1}{2}''$, window $\frac{3}{4}'' \times 2\frac{1}{4}''$.

Primary, 460 turns of No. 26 enameled copper for 115 volts.

Secondary, 1100 turns of No. 26 enameled copper consisting of two coils tapped as follows: *A*, start; *B*, one turn; *C*, ten turns; *D*, one hundred turns; and end at *E* one thousand turns. Total of this arm 1000 turns. *F*, start; *G*, one turn; *H*, ten turns; and end at *I* one hundred turns. Total of this arm one hundred turns. *A* and *F* form the center tap and the coils are so wound that the voltages are additive and as connected form a 1100-turn secondary. They are wound as separate coils so that the single-turn taps are one turn each of the same length and next to the core, etc., instead of a continuous coil which would bring these turns to positions that would produce a great difference in length. Maximum turns give 275 volts impressed across the bridge. Minimum turns possible is the 1-to-1 ratio giving 0.5 volt.

We have used several types of null indicator to show balance: head phones, a d-c. galvanometer used with a Cuprox rectifier, an a-c. milliammeter and a tuning eye tube in conjunction with one stage of amplification through a '56 tube. This last combination is the best and the head phones prove next best as well as most convenient.



This being an a-c. bridge, it is adaptable for measuring capacitance or inductance and is so used, however, when used for this purpose it must be remembered that no true null point will be reached and balance must be made to a minimum point instead of a null as the arms *X* and *Y* being capacitive, their center point will be at a different phase relation to the center point of the secondary coils represented by *A* and *F*. This offers no drawback to any indicating device to show a null but the head phones, which will generally refuse to show any null and the ear does not easily detect the point of minimum volume.

Constructional details may be changed to meet any local condition as the above is no fixed standard but a new application of potential to the arms of the old much-abused bridge.

INSTRUMENT SOCIETIES CALENDAR*

CITY	DATE	PLACE	SPEAKER	SUBJECT	SOCIETY	SECRETARY
Baltimore	Aug. 14	Maryland Academy of Sciences	Organization Meeting		No Name Announced	C. A. Baker, E. I. duPont deNemours & Co., Curtis Bay, Baltimore, Md.
Chicago	Sept. 14	St. Clair Hotel	Robert Brown, Director, Tech. Development, Chicago Office WPB	How Can I Help Win the War	Chicago Society for Measurement & Control	Carl Hope, 2626 W. 31st Blvd., Chicago, Ill.
Hartford	Sept. 15	Auditorium Hartford Electric Light Co.	I. A. Hunt, Federal Products Corp.	Gaging	No Name Announced (Organization Meeting)	Stephen J. Zelle, Chief Inspector, Whitney Chain & Mfg. Co., Hartford, Conn.
Newark		No Meetings Announced at this time			Society for Measurement & Control (N.J.)	R. F. Robey, 409 Orange Ave., Cranford, N. J.
New York	Sept. 29	Roosevelt Hotel	Organization Meeting		No Name Announced	George Kauer, Jr., 4155 Case St., Elmhurst, L. I.
Philadelphia	Sept. 16	Engineer's Club	Organization Meeting		No Name Announced	H. J. Boyce, Eng. Dept., Philadelphia Electric Co.
Pittsburgh		No Meetings Announced at this time			American Society for Measurement & Control	L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pittsburgh

*Meetings begin at 8 P.M., Dinner served at 6:30 P.M.

On the Language of Instrumentation

A Simple-minded Ignoramus Discusses Some Problems of Terminology, Letter Symbolism, Graphic Symbolism, etc.

Though based on lecture notes prepared over a number of years for oral presentation on various occasions, this article is simply AN ARTICLE of interest to forward-looking readers of *Instruments* and in no wise does it commit or involve any university or scientific or technical society which has scheduled a similar lecture in the past or may do so in the future.

By VERBA VOLANT SCRIPTA MANENT

What is in a name? That which we call a rose, by any other name would smell as sweet. —WILLIAM SHAKESPEARE.

Some to the fascination of a name surrender judgment hoodwinked. —WILLIAM COWPER.

IT is logical that the first lecture on the program should be on the most elementary topic—and "elementary" in this connection does not mean a freshman topic, nor a primary-school topic, nor a kindergarten topic . . . not even the A B C but those exciting years between two and five, when the child has begun to speak—that is to say, not merely to utter words but to *use* words. For even a kindergarten will not "matriculate" a child who, though neither deaf nor dumb, has not yet learned to use words purposefully—a child who says "Take your small dolly" when he means "I want my big marble."

It is logical that this topic should be assigned to an ignoramus. As our anthropoid ancestors progressed beyond grunts and growls and guggles and gaggles, they managed to "teach" easy and obvious but adequate NOMENCLATURES to their young: dada and mama; wawa for "water," voozevoozevoo for "fly," as well as kookoorikoo, miaow, krikri, and lots of other onomatopoeiae, some of which survive. Then our Stone Age ancestors managed to teach adequate VOCABULARIES to their young. More recently, Bronze Age people managed to teach adequate LANGUAGES to their children. Since the development of writing, and even of printing, literacy has not been a requirement for teaching infants to talk. It isn't necessary nowadays to hire a Nobel Prize winner in chemistry or physics—or linguistics—as nursemaid to teach a child to say "I want my big marble." In fact, when average parents have to be away all day, they prefer ignorant and simple-minded nursemaids. It seems that the more ignorant and simple-minded the nursemaid, the quicker she teaches children to drop "baby talk" for true speech, the more capable she is—and the greater her just pride of accomplishment, so that on her next job she is even more efficient. . . . A Program Committee likewise displays good judgment in assigning an elementary topic to a simple-minded ignoramus.

The topic is not the "baby-talk" of Instrumentation—not the nomenclature or the vocabulary but the Terminology and Symbolism, that is to say the Language. On the other hand the topic is not the sophisticated language which evolves in the course of years, not even the slang of the high-school campus, but the elementary and essential language of the kindergarten—the Basic Language, if you please, whereby a child who means to say "I want my big marble" *says it*, and doesn't say "Take your small dolly."

Of course the present situation isn't that bad. Let us take a look at the good and bad sides of it—not a scrutiny but a superficial glance.

THE GOOD SIDE is that most of the articles, classroom courses, etc., on testing, measurement, gaging, inspection and even automatic-control subjects are understandable by most of the readers and hearers addressed in each case. The terminology and symbolism of most (if not all) of the apparatus articles appearing in *Industrial & Engineering Chemistry* (for example) can be understood instantly by most (if not all) of the regular readers of that excellently-edited journal; and the same is true of the articles in, and regular readers of, most other justly-famous scientific and technical journals. Each technical journal and technical book publishing company adheres to some standard of style with regard to abbreviations, symbols, etc. Every teacher—whether a permanent professor in a university of a volunteer in charge of a War Effort course—makes himself understood by his own students.

Likewise, there is one language within each of certain instrument-conscious industries or occupational fields such as weights-and-measures men. Also within large instrument-conscious companies such as oil companies, chemical companies and other large "users." Also within companies manufacturing "complete lines" of calipers and gages, or of chemical laboratory apparatus, or of aircraft instruments, or of combustion-control systems, or of gas meters and pressure regulators, or of pyrometric equipment, or of optical products, or of meteorological apparatus, or of surveying instruments. (By the way, the sales engineers of these companies, visiting different industries as they do, are helping to construct a common language.)

Likewise, in certain fields there is nearly-perfect conformity with lists of terms and definitions issued by representative bodies. The lists issued by the Scientific Apparatus Makers of America, and by the Instruments and Measurements Committee of the American Institute of Electrical Engineers (to cite only two) pertain largely or almost exclusively to certain classes of instruments. Other lists, of course, contain fewer and fewer instrument terms until we get down to the standards of certain trade associations which define only incidentally, as it were, the terms pertaining to gaging, weighing, inspecting, etc.

THE BAD SIDE has become fairly apparent from the nature of the foregoing glance at the good side. (Yes, it was such a quick glance that it was perhaps more of a leer than a look!) In the first place, the numerous official terminologies are not uniform. In the second place, each list serves one distinct circle which in no case is co-extensive with the field of Instrumentation (and *ex vi termini* cannot be, for IT would be Instrumentation under another name).

In the third place the languages of even the best-edited scientific, technical and trade journals differ from one another insofar as instrument terms are concerned. Mild examples: A member of the Institute of Radio Engineers who is used to the *I.R.E. Proceedings* may not understand the symbol "ml" in an *I. & E. C.* article because he may be used to "c.c." A biologist used to lbs./in.^{2} may not understand PSI. A chemist who comes across 2 F or 4 C or 100 K in *Trans. A.S.M.E.* may think two atoms of fluorine or four atoms of carbon or a hundred atoms of potassium are meant, because the degree symbols and periods to which he is used are omitted.

Thus there are a number of language circles. This is natural because each occupational field has more or less of a vernacular of its own—a vernacular which in some fields includes numerous measurement and control terms and symbols.

Even within each language circle, we find numerous intrusions of "foreign" terminology. For a purely hypothetical (but typical and light-throwing) example, let us start at the head of the alphabet with "American" and take a product-class name, say, "meter." That gives us the American Meter Company. We take an engineer employed by that company. He understands perfectly all of his own company's literature. He can readily understand the technical bulletins put out by all other gas-meter and pressure-regulator companies because the Basic Language is the same although the subordinate nomenclatures differ

accidental affinity or coincidence of a name, connected with ... or hatred, with pleasure or disgust, has operated like ...
—BENJAMIN DISRAELI.

... suppose their reason has command over their words; still ... happens that words in return exercise authority on reason.
—FRANCIS BACON.

... knowledge of words is the gate of scholarship.
—JOHN WILSON.

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slightly. He can understand most of the contents of the half-dozen gas and petroleum trade and technical journals . . . most but not all: one day he reads in one of these technical journals an item about a gas-analysis apparatus. He sees a reference to "a 2″ meter" and assumes it means a 2″ pipe-size gas meter; but he is completely baffled by the context which refers to thermometry. No wonder he is baffled: the so-called 2″ meter is not a meter at all but an electrical indicating instrument; and its function is not to meter anything but simply to indicate the inlet temperature. Such foreign-language intrusions are noticeable in the new-product columns of the great majority of technical journals. You'll find "dolly" in lots of places where it should have been printed "marble" because the thing referred to is called a marble by the occupational circle served by that particular journal—is called a marble by the editor himself! Unfortunately, it seems that there is only one technical journal which corrects the terminology and symbols in *all* pieces of copy from the longest serials to the briefest new-product descriptions.

The usual one-word reason for the diversification of language circles ("specialization") is not the whole story. A deeper reason is that great scientists, engineers and inventors, whose brain-children made possible the marvels of modern instrumentation, could not have foreseen the polyandrous and polygamous intermarriages of their brain children's descendants in our complex industrial civilization. This is "the age of specialization" but any single specialty stems from perhaps four parents and sixteen grandparents —each blood a linguistic type—so that a specialist in one model of one make of one species of control system uses a mixture of terminologies.

A propos of the march of science, another factor contributing to the "bad" side is a purely incidental consequence of a sublimely good thing, namely, Discovery. The more prolific a worker in pure science, the greater the number of new terms or new meanings for old terms he finds it necessary to use. The more applicable his discoveries to Instrumentation, the more will his terms carry weight among instrumenticians—and cause confusion when the field of application of his discoveries overlaps other Instrumentation fields previously endowed with terminologies.

One more glance at the present situation—at a side which is not good but not bad. Even within some harmonious language circles, perfection is marred by *legitimately* ambiguous terms—some of them already ambiguous in everyday English. The other day, a bright Quiz Kid type of lad stumped me with this one: "How can you double your money without risk?" (Answer: by folding it.) The ordinary-English word "fast" is a noun, an adjective, a verb and an adverb and probably has altogether ten or twelve different meanings. There are two serious reasons for mentioning this subject: First, to caution against too-hastily *adopting* any more terms and symbols than we have to; second, to plead that we should all strive to refrain from tacking on any *additional* meanings to already-overworked terms (such as "meter" and "sensitivity"). For the sake of future clarity as Instrumentation ramifies and diversifies, gentlemen, please think up new terms instead of using any old one that sounds good when you have to name some new thing or some new relation-between-things, or some new property or characteristic or whatever it is . . . yes, even if Sales is cussing out Engineering because you're late with that N.P.D., yes, even if it is an hour before air-mail time for the closing date! A new term which doesn't click can be allowed to die away but a new meaning for an already multi-meaning term has a nasty way of insinuating itself into the minds of whatever circle it reaches; and then the inter-circle Babel is worsened.*

Considered purely as words, "atom" and "vacuum" have a striking feature in common. Both, by their origins, bespeak an ultimate and an absolute character, such as no human conception has really a right to claim. . . . Now, "atom" is by its Greek meaning that which is indivisible. And yet, will anyone ever dare to say at any time that the particles which at that time seem indivisible are always going to remain so, whatever new forces, powers, and techniques may be derived by coming generations? . . .

It is recorded that once at a party Kelvin was inveighing against people who talked of subdividing atoms, when a young man in the company spoke up and said, "There you see the disadvantages of knowing Greek!" Well, it *would* be a disadvantage to study Greek if one should emerge from the classroom with the demand that "atom" must mean that-which-is-forever-indivisible; this would devitalize the word, which would become as futile as would "vacuum" if the latter were obliged to mean a perfectly empty space. To demand that "atom" shall mean that-which-now-seems-indivisible would not be a good idea either. We should have to be transferring the word every now and then from one candidate to another, like a championship cup whose winner holds it only until some newer and better contender comes along. (Something of the sort has been happening to "vacuum," but this does not make it desirable.) Then, there is the highly important point that when we succeed in breaking down the so-called atom of any element—let me take gold for an example—into particles even smaller, some at least among these particles are not by any means uniquely characteristic of gold, for they are ordinary negative electrons such as exist in every substance. If we transfer the name to these, we must call them not atoms of gold but atoms of negative electricity; which being the case, why should we remove the title "atom of gold" from the particle which has a historic right to bear it? There is not a physicist or chemist in the world, so far as I know, who will not repudiate the etymology rather than be forced to such a step as that.

Well, etymology is after all not sacrosanct. Plenty of words have reversed their meanings in the course of the centuries; in another hundred years it may be considered pedantic to remind the world at large that *atom* once meant *indivisible*.
—KARL K. DARROW, *The Renaissance of Physics.*

The final glance at the present situation is of necessity in the nature of an introspective glimpse—or a look into the mirror, if you please—for it cannot be objective. Anyway, mention may be made of a magazine devoted to measurement, inspection, testing and control, so that its circle is fairly co-extensive with the field of Instrumentation. For more than a decade—the decade witnessing the fastest growth of that field—this magazine has been using a language which perhaps more than a handful of its readers are kind enough to accept as THE Language of Instrumentation. As will be shown later, it is against logic and ethics for any single language-source to make such a claim for itself and deny the rights of all other possible claimants, in the course of a serious dissertation such as a lecture or article. It is a plain fact, however, that the magazine referred to, circulating as it does in all industries, in the technical Services of the Army and Navy, etc., helps unification and prevents the inter-circle Babel from becoming even worse; so that all other language-sources might . . . but such gestures should come spontaneously! Let us see what could be done as if no such central medium existed. Let us see what the ideal language of Instrumentation should be or might or could be.

* * *

To some workers, Dantzig's best-seller, *Number, The Language of Science*, may suggest settling this whole question of language by the following syllogism: mathematics is the language of science; Instrumentation is a science; therefore mathematics is the language of Instrumentation. But this is defective: the correct syllogistic form would be, "*All* sciences have mathematics for their language; Instrumentation is a science . . ."

We must stop right there! In the first place, only the *quantitative* sciences have mathematics for their language. In the second place, there is only one entirely quantitative science. In the third place, the corrected minor premise ("Instrumentation is a quantitative science") remains to be accepted as "true" by a "sufficient number" of "interested persons" or by a "sufficient proportion" of all

*Recommendations should go at the end but this important one is pur. osely inserted here—before the audience walks out.

scientific and technological individuals or "duly representative" organizations. A simple-minded ignoramus who since 1924 has advocated using the word Instrumentation to denote a distinct science (actually "a distinct *branch* of Science and Technology") might be forgiven for thinking that today the majority of those who utter this word and write this word (using it in its new non-musical meaning) do so with the awareness that it signifies a science, or a branch of Science. *He doesn't think so*, for that would be wishful thinking! The great majority of workers in all sciences and in all technologies who design, make, sell, buy, install or use measurement or control instruments have not yet learned to associate the word "instrumentation" with a science. Nay, many of them (still a majority when you consider them all) have never uttered or written the word "instrumentation"—though by this time a majority of those in America may have seen it in print.

Thus, even the uncorrected minor premise remains to be *established*. You keen-witted scholars—and this simple-minded ignoramus—*WE* know that Instrumentation is a Science . . . but "the world" doesn't. Moreover, all of "the world" is not merely indifferent: a portion of it ridiculed the idea from the start and still displays fierce opposition. Of course we *could* ignore "the world"—but we *should not* . . . because our purpose is to benefit the world and not to benefit ourselves at the world's expense.

So then, among ourselves it is permissible to say that Instrumentation is a science; but when we speak objectively we cannot maintain the Absolute or universal truth of the proposition "Instrumentation is a science." Does this sound like a riddle? Do we have to abandon our view for that of our adversaries in order to be honest with ourselves? To a simple mind, the solution is to modify the proposition: we can safely assert—not only among ourselves but from the rooftops—that Instrumentation is an embryonic science. In fact, we are all fairly safe from contradiction if we say that Instrumentation is an infant science.

To most mathematicians, of course, it may seem that the best way to bring up an infant science is to teach it the language of mathematics. It certainly is a good way. But it is not the only way. Moreover, if this promising infant is taught the language of mathematics and no other language, he will not grow up into a normal boy and then into a well-rounded man. It never will *and must never* become an entirely quantitative science. Only for its metrological aspects will mathematics ever suffice. It will always have qualitative aspects. And the refinements and ramifications of its quantitative aspects will require many long years of interchange and development of hard-to-grasp ideas—concepts which individual minds apprehend vaguely at first and cannot possibly convey to other minds through the medium of equations—not even through simple numbers—because at that stage no single, isolated isolated *magnitude* can be converted into a *quantity*.

Some examples will be given later but this point must be driven home now, so here is one impressive example, a quotation from the greatest American authority on certain properties of matter whose generic name is "hardness":

> Would it clarify our thinking if we eliminated the word "hardness" from our scientific vocabulary? The author's point of view is that the term is so firmly entrenched in our everyday vocabulary, that we wouldn't go far before we began to use it again. For instance, one could talk about measurements of penetration, or measurements of machinability, scratchability and other terms already used. Whatever we call it, back of each measurement is a something which we might just as well call hardness from the start and keep on calling it that, until we know something about it.
>
> SOCRATES: But why should we dispute about names when we have realities of such importance to consider?
> GLAUCON: Why, indeed, when any name will do which expresses the thought of the mind with clearness?
> —PLATO, *The Republic*.
>
> —S. R. WILLIAMS, *Hardness and Hardness Measurements*.

Here is another example. When a differential equation is designed by the mind of one worker to say "give big marble," it shouldn't come out as "take small dolly" when read by another worker. Yet this seems to be happening

> Words should be employed as the means, not as the end: language is the instrument, conviction is the work.
> —SIR JOSHUA REYNOLDS.
>
> The finest words in the world are only vain sounds, if you do not comprehend them. —ANATOLE FRANCE.
>
> Words are but the signs and counters of knowledge, and their currency should be strictly regulated by the capital which they represent. —CALEB C. COLTON.

in the formulation of certain time effects in closed dynamic systems consisting of controllers and applications. Apparent reason: the combinations of terms, letter symbols and diagrams probably represent neither practical physical realities nor exact physical ideals such as the "ideal gas." (I committed that very sin ten years ago.)

It certainly isn't the fault of mathematics; and these two examples are not to be construed as objections to mathematics. Nobody can successfully take a stand against "the handmaiden of the sciences" or "the Queen of the Sciences" and all of us agree with Einstein that "it is mathematics that offers the exact natural sciences a certain measure of security which, without mathematics, they could not attain." But the difference of opinion arises from the fact that not all of Instrumentation is "exact natural science." Instrumentation is other things than even an infant science. It is a science but it is at the same time an art and . . . well, lots of other things.

"Well, then, what is it?" the impatient question is asked. This question should be "answered" because the term INSTRUMENTATION* heads the list in our minds and its definition—if possible—would settle hundreds of separate but dependent minor points.

DEFINITION AND DEFINITIONS

No simple answer can be given, because no simple description is possible of a phenomenon which has not yet assumed a definable shape: Instrumentation is like a fast-growing tree whose roots and branches are constantly multiplying. It is like the banyan tree which sends, from some of its branches, downward shoots which take root and eventually develop into accessory trunks so that the tree becomes a grove.

No simple answer can be given by any individual today and accepted as true by all others, because among these others there have appeared in the last few years some twenty or thirty who each has contributed valuable roots or branches or accessory trunks (each the main trunk now!) and hence can claim the right to describe the tree or the grove.

No simple answer can be given, because—because of other reasons which would only bore you.

The answer, then, would have to be a lengthy and complicated definition. But lengthy and complex definitions, as a rule, do not really define.

And yet an answer to the question "What is Instrumentation" can be formulated. There is at least one precedent for such formulation—a precedent in a related field—a precedent which may well be worth following, and which *will* be followed.

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*Footnote especially for new subscribers to *Instruments*—and a million apologies to older subscribers who know the story:—
In January 1924 Victor Wichum (Chief Engineer, C. J. Tagliabue Mfg. Co.) William C. Begeebing (Ass't Ch. Eng., same Co.) and I had a dinner conference; purpose being to acquaint me with a phase of the outside work they were doing, which was being designed to benefit an entire industry (and eventually did). Although I had started designing and building instruments twenty years before that date, I had never realized the difficulties of "Application Engineering" and I made several admiring comments to the effect that this work of Vic and Bill (and hundreds of others like them in various instrument-**making** and instrument-**using** companies) deserved greater recognition from the leaders of American industry and from engineering schools and societies. In the course of the evening the word Instrumentation was uttered several times—half earnestly and half jokingly—as a sort of highbrow term for "Application Engineering." Who first uttered it I do not remember. Vic and Bill later said I did but I think it was Bill: much clever**er** than I and with a gift for epitomization. Several days later, when I deplored the lack of any book on Principles and Applications of Industrial Measurement and Control Instruments, along the lines of existing engineering texts each so valuable in its field, Vic snapped out "Well, you're a writer. Why don't you write it?" and the word Instrumentation naturally came to my mind as a shorter title. So, as I've always maintained, Bill Begeebing deserves credit for the word. Vic Wichum deserves credit for starting me off . . . and all I deserve is blame for taking four long years (1924-1927 inclusive) to make a real start in organizing a hundred men representing manufacturers, institutions, technical societies and other sources of information. But highest credit is due my august father who, to the day of his death, always dissuaded me from merely grinding out a mechanic's pocket handbook, always inspired me to establish a perpetual project and to strive to create a new profession and formulate a new science—a triple task far beyond the puny strength of a great man's mediocre son.—M. F. Béhar.

quotation from *Hardness and Hardness Measurements* by Williams has already been given to prove that before we can apply mathematics we must isolate and name and define the entities to which we desire to assign numbers. Further on, Professor Williams makes the following statement:

> . . . the proposition that hardness can be measured by the load required to produce a definite penetration of the material under test . . . "It is," as Béhar has said, "all a question of definitions: if some body of men proclaims that hardness is 'the diameter of a ball's impression,' 'the angle of a pendulum's rebound,' 'the force to produce a given impression,' or what not, it is just that—as far as that body of men is concerned."

Professor Williams has been investigating hardness for more than thirty years and has enriched scientific and technical literature by more than sixty outstanding papers and three important books. And yet, he not only rebukes (in a gentle implicit way) those impatient questioners who would blurt out "Well, what is hardness?" but the nearest thing to an answer in his whole book is that one which he so graciously quotes.

Now you know what to expect . . . and here it is:

If any body of men proclaims that Instrumentation is

(1) the controls of an airplane;
(2) the equipment of a testing department, or
(3) the auxiliaries of a processing apparatus; or
(4) the craft practiced by the dues-paying members of Local 9999A; or
(5) the art of making optical apparatus and fine mechanisms; or
(6) the branch of engineering which deals with automatic machines from bar-room slot machines to anti-aircraft fire-data-computing machines; or
(7) the design of A or B or Z only [or A-Z]; or
(8) the design and development of A, B . . .; or
(9) the design, development and construction of A, B . . .; or
(10) the design, development, construction and sales engineering of A, B . . .; or
(11) the design, development, construction, sales engineering and specification of A, B . . .; or
(12) the design, development, construction, sales engineering, specification and application of A, B . . .; or
(13) the design, development, construction, sales engineering, specification, application and installation of A, B . . .; or

A—Gages, calirers and other linear measuring instruments;
B—Indicating instruments in general, including those for measuring variable magnitudes;
C—Recording instruments;
D—Testing machines and instruments;
E—Inspection equipments;
F—Optical and precision laboratory instruments;
G—Telemetering systems;
H—Prime-mover governors, furnace controls, etc. ["which we who make them do not call instruments"];
I—Meters;
J—Automatic controllers;
K—Electric motor "controllers" and switchgear;
L—Photoelectric and electron-tube devices, even if not "measuring";
M—Valves, dampers, etc.
N—Clockworks, etc.
O, P, Q . . . X, Y, Z [products]

(14) the design, development, construction, sales engineering, specification, installation and operation of A, B . . .; or
(15) the design, development, construction, sales engineering, specification, installation, operation -and maintenance of A, B . . .; or
(16 to 22) the design and/or development and/or . . . [all the way to maintenance like 9 to 15] of A and/or of B . . . and/or of Y and/or of Z; or
(23) the subject assigned, as per Resolution No. 57 of the 99th Annual Convention, to the Instrumentation Section of the Robot Committee of the International Gadgeteering Academy; or
(24) the course of lectures by Xenophon X. Xavier given at Dear Old Siwash—don't you dare mention Quentin Q. Quarrelsome's flop at Minntuckiana State!; or
(25) the body of knowledge contained in Angstrom A. Astra's *Handbook of Famous Telescopes, Schmidt Cameras and Spectroscopes;* or
(26) the body of knowledge contained in Dulcet D. Decibel's *Encyclopaedia of Acoustimetry, Audiometry, Vibrometry and All Other Instruments;* or
(27) the body of knowledge contained in Melodius M. Metronome's *Treatise on Instrumentation, Orchestration, Harmony and Counterpoint;* or
(28) the body of knowledge contained in Modulus M. Megacycle's *Introduction to Instrumentation and Broadcasting-station Engineering;* or
(29) the body of knowledge contained in Tempus T. Tempora's *Manual of Horological and Other Instruments;* or
(30) the trend in public-utility management which favors the abolition of flat-rate contracts and the substitution therefor of scientific maximum-demand contracts; or
(31) the field served by such-and-such a company; or
(32) the scope of such-and-such a journal; or
(33) the province of such-and-such an institution; or
(34) the sphere of such-and-such an association; or
(35) the profession practiced by "Instrumenticians"; or
(36) the movement launched by so-and-so at such-and-such a date and having as its object the formation of societies, the giving of educational courses, etc.; or
(37) the philosophy based on (a) the proposition that the conditions of human society and of industrial processes and operations—i.e., the "forces of Nature"—should be controlled; (b) the principle that before a condition can be controlled it must be measured; (c) the dictum that in order to measure a condition or property it must be segregated; (d) the slogan "If you control it manually you should control it automatically"; or
(38) the perpetual project started by so-and-so at such-and-such a date with the object of publishing and continually revising "parts" and chapters on the Theory and Application of Industrial Measurement and Control Instruments [or a shorter title]; or
(39) the common interest, curiosity, fascination, inclination, enthusiasm, attraction, devotion, . . . etc., which binds us together,

it is just that—as far as that body of men is concerned.

* * *

NO, this is not an admission that anarchy prevails or that chaos is desirable. It is a proclamation of equal rights and it implies—as always in any decent human society—the golden balance of privileges and duties, of authority and responsibility.

To a simple mind it seems that this form of answer should please every body of men concerned. Certainly, it does not affront any body of men (or any individual, for that matter) for it *affirms* the right of all of them to write and issue definitions of the term Instrumentation.

Moreover, this answer implicitly affirms three further rights: (1) their right to coin or adopt and to define various and sundry Instrumentation terms; (2) their right to adopt various and sundry Instrumentation letter symbols; (3) their right to decide upon various and sundry Instrumentation graphic symbols.

One may as well go the whole way from the implicit to the explicit. All these rights are hereby explicitly affirmed.

(There has been a rumor that a **M**aliciously **F**erocious **B**rute denies these rights to others. The rumor is false and there ain't no such animal—only a **M**ild **F**aithful **B**ear or perhaps a **M**erry **F**rolicsome **B**ear.)

Difficulties because there are perhaps forty "bodies of men"? Why? Think of forty people riding in a bus—most of them strangers to one another but all with a common destination. If a couple of them suddenly decide to go elsewhere, they will get off—unless they suffer from the abominable Prussian or Nazi tendency to impose their will on the others . . . in which case the American nearest them will drop his newspaper and, spontaneously obeying the inner voice of duty, will toss them out to restore peace without waiting for a policeman.

It is not too idealistic to expect (not hope but expect) that each "body of men" will yield some of its "sovereignty" as all of the Thirteen Colonies did. But it would not even be that: it would only mean dropping a small

proportion of the hundreds of terms and symbols it uses (in some cases only two or three) and adopting better ones.

To a simple mind it seems that everything will go well if all concerned bear in mind the thirty-ninth and last definition: that Instrumentation is the common devotion, enthusiasm and interest of not one body of men but of thousands —perhaps tens of thousands—of earnest workers in industry, in research, in education, and now in the Armed Forces. If this is granted, then it follows that there is not only a *demand* for a common language—a demand often expressed in the last fifteen years or so—but a great *need*—a need felt by thousands and perhaps tens of thousands who have not formally asserted that there exists such a need.

It may be well to recognize also that Instrumentation is also the *opposite* of an abstract common interest—that it is an immense variety of commercial products.

Between these two extremes, most interested persons will assert—and only few will deny—that Instrumentation is some sort of occupation, even if only a part-time occupation, as well as some sort of art or science.

A second glance at the thirty-nine hastily-reported definitions will disclose the possibility of universal and harmonious agreement on several broad definitions; and a closer study will bring a sharper general picture into the minds of persons who had only thought of Instrumentation in only one or two of these senses; and this picture, in turn, will suggest the nature of the common language to be broadly adopted and broadly constructed. Even if it only suggests the *level* of the desirable common language (somewhere between Eddie-the-dope and Einstein) this will be a great step forward.

* * *

It is realized, of course, that the first obstacle in the way of an idealistic or altruistic undertaking of broad scope is the question, "Who is to make the final decisions?" To a simple mind it seems that this question need not come up because it is not "who" but "what facts and what methods." A few years ago, a slogan frequently found on the walls of advertising and publicity campaign offices read somewhat as follows: "Get the facts and the facts will point the way." It is a good slogan because it stems from the words of our Lord, "Ye shall seek the truth, and the truth shall make ye free" as well as from the foundation of all sciences. Therefore the common language can come about by a logical and rational procedure based on

(1) the facts,
(2) the weighting factors,
(3) the application of Methodology.

The *facts* are readily ascertainable today. No need to go after recondite ones depending on opinions. The task can be simplified by abandoning—only during the process fact-gathering—the idealistic side. The saying—

> "Let us start by considering what binds us together. Meters and gages? No: more than instruments—Instrumentation."

can be reversed temporarily, as follows:

> "Just what are we after, now? Instrumentation? No: merely statistics on gages and meters and controllers, data on their varieties, on their principal uses, on their distribution in various fields, etc."

The *weighting factors* are not entirely physical. Opinions play a part. Obvious solution: convert "opinions" into "the consensus."

As to *Methodology*, it is a terrifically tedious scientific discipline. It is the combination of physical or technical procedures, and of mental or logical processes, which has slowly been built up by some of the greatest minds of history—idealistic philosophers and practical research workers. The "natural philosophers" of the 18th Century made great contributions—particularly Linnaeus with his *Philosophia Botanica*. . . . Yes, you have guessed it, much of the work deals with scientific classification, with inductive and deductive inferences, with analysis and synthesis, with the search for causal connections, similarities and contrasts, agreements and differences, statistical methods . . . and just about all the dry subjects you have heard of—or never want to hear of! (As a sample of the light reading with which a simple-minded ignoramus brightened his spare time, there is recommended a delightful little treatise by Professor Wolf of Cambridge University. Its title is *The Existential Import of Categorical Predications.*) Fortunately, this part of the job—the application of Methodology—can be left to those who enjoy it. Although it is No. 3 on the foregoing list, it naturally comes first. And it actually came first when the formulation of the language of Instrumentation was undertaken in the nineteen-twenties.

Methodology is a tedious scientific discipline but it yields rich fruits in the field of Instrumentation even when applied in a simple-minded and ignorant way. For example, when a simple-minded ignoramus had to edit a manuscript on the subject of hardness, his training in methodology led him to say, "Instead of one definition which is impossible, let there be as many definitions as there are bodies of men who put them forth."

In fact, there are ten or twelve instances on record where the deliberate application of methodology has been fruitful in the field of Instrumentation. This point needs to be stressed, because it is difficult to convince many of those who want a common language of Instrumentation (even many of those who are willing to work hard) that there is no royal road to the attainment of their objective—to the attainment of our common objective. The road is hilly and rocky, and its name is Methodology. It must be traveled—traveled on foot, mile by mile—and there is no land vehicle to speed the trip, nor airplane to short-circuit the route.

There is no mystery about the combination of technical procedures and logical processes known formally as Methodology. In limited cases it is practiced unconsciously by technical workers who have never heard of it. In limited cases its application, put in plain words, is simply to "get the overall picture and then break it down." Yes, "get the overall picture and then break it down" has helped to settle many differences of opinion. For example, all of us know today that the field of Instrumentation coincides almost exactly with the field of industrial instruments, though not to the absolute exclusion of all scientific instruments. The design and construction of the great 200″ telescope and its associated buildings has not been, and its use will not be, all within the province of Instrumentation, but many details of the design and construction of the telescope itself and of the buildings, have interested many instrumenticians. Moreover, industrial instruments have evolved from scientific instruments and thus we are all indebted to the scientists of the past and of the present.

The "overall picture" grew slowly in the 1920's. Physically, it had filled a four-drawer filing cabinet by 1928. Some time later a request was made that this overall picture be actually put on paper, and in compliance with that request it was published in *Instruments* in 1930, occupying three pages. With some minor revisions it was republished in a book in 1932, and is reproduced on the facing page.

Note that this is only one not-so-important result of only one part of "getting the overall picture and then breaking it down." This particular method consisted in ascertaining, from the contents of a filing cabinet, what were the "measurables" to which industrial instruments were applied, and then dividing the measurables into mutually-exclusive categories. Some definitions resulting from the consensus method—by correspondence at the time—are appended.

To jump to the present—and to peer into the future: an example of the need of getting the overall picture is afforded by almost every term which might come up for adoption into our definite common language. Starting from A we take as an example *Automatic-reset*. Some members of the language circle which is related to the control of temperature, flow, liquid level and pressure, think that this term was coined about ten years ago. Let's dig out the facts. Here comes Fact Number One: Actually, this term has had a definite meaning (strictly two meanings: one morphological and the other operational) for perhaps more than thirty years in one of the largest fields of automatic control—a field comprising nearly a hundred manufacturers serving not only all industrial markets but the domestic market and

TABLE I—TENTATIVE CLASSIFICATION OF ALL INDUSTRIAL (& SOME OTHER) INSTRUMENTS ACCORDING TO OBJECTS OF MEASUREMENT OR CONTROL.

PARTIAL LIST OF OBJECTS of Instrumental Measurement or Control			EXAMPLES AND REMARKS		
Classes (Complete list)	Groups	Individual objects	Some examples of various methods or MEASURING instruments	Some examples of automatic CONTROL instruments, or notes on control	Other remarks
I THE TEN industrial processing, working and operating CONDITIONS	1. Thermal	Heat	See Class II.	Heat is the property, temperature the condition	
		Temperature	Thermometry: expansion, resistance, etc. Pyrometry: optical, thermoelectric, etc.	Thermometric controllers Pyrometric controllers	Distinctions between industrial and non-industrial instruments, and classifications of former, are given in Chapters V and XIII.
	2. Hygrous	Absolute humidity Relative humidity	Absorption, etc. Psychrometry, hygroscopy, etc.	Psychrometric and hygroscopic controllers	
	3. Pressure (a) Liquid and gas	Vacuum Absolute pressure Gage pressures—"low" "medium" "high"	Liquid head, Bourdon tube, inverted bell, bellows, etc. Also static or differential. Also classified according to range. Also primary or secondary types.	Most forms of automatic control devices (and greatest number in use) are not indust'l **instruments.**	
	(b) Miscellaneous	Plastic pressures Mechanical pressures	Carbon piles, cylinders, crystals, magnetic, elastic deformation, etc.	Apparently very little industrial automatic control	
	4. Flow (a) Fluids in pipes	Quantity Rate	A. S. M. E. classification of methods (primary elements) is followed. Also must consider classes of fluids in industries	Industrial viewpoint here requires classification distinct from that by primary elements as with flow **measurement.**	
	(b) Fluids in open	Quantity Rate			
	(c) Granular and plastic materials	Quantity Rate	Coal meters, etc.	Stoker feed control, etc.	See also under Weight.
	5. Liquid level, etc.	Liquid level Position.	Not only tank gages but all industrial position indicating and recording systems	Control usually indirect, **flow** being in most cases the controlled factor.	Under this head may be considered all remote-indicating and recording systems.
	6. Electrical a) Current electricity	Quantity, Current Emf, Power, Energy, Power factor, Frequency, Phase, Etc.	Ampere hour meters, ammeters, voltmeters, wattmeters, demand meters, power factor meters, frequency meters, synchroscopes, etc.	Electricity is itself the essential condition in some processes. Examples: For current electricity: plating, refining, production of Cl, H_2, O, O_3, N, etc.; static electricity: Cottrell process; magnetism: ore separation, etc. Electricity is also the producer or regulator of non-electrical processing and operating conditions. Such is the criterion for "industrial" electrical instruments. Under this heading also come electrical details of pyrometers, tachometers, etc., for measurement and control of non-electrical conditions.	
	b) Static electricity	Quantity, Potential, etc.	Few strictly industrial instruments.		
	c) Magnetic	Quantity, Flux, Intensity, etc.			
	7. Temporal	Time— Duration Sequence	Time recorders Operation recorders, chronographs, etc.	Timing controllers Sequence and "program" controllers	Timepieces are not industrial instruments but clockworks are embodied in many ind'l instr's.
	8. Speed	Angular velocity Linear velocity Angular acceleration Linear acceleration	Counters: centrifugal, magnetic, electric, etc. Tachometers, tachoscopes, stroboscopes, etc.	Only the industrial forms of speed control instruments—engine governors, etc. being excluded.	Only speed of parts, etc. Velocity of fluids and materials comes under Class I, Group 4—Flow.
	9. Chemical	"Strength" of processing medium. "Atmosphere," etc.	Classes of industrial instruments are exactly same as under II, 2.	Controlling potentiometers, etc.	Only condition of processing **medium,** not of processed material.
	10. Radiant energy	Visible: quantity, flux, intensity, illumination, insolation, etc. Ultra-violet X-rays, gamma-rays	Indicating and recording photometers, etc. UV ray meter, etc.	Visible light is not only a working condition but an essential processing condition, as in chemical processes. Ultra-violet irradiation of food products, etc., is now a recognized processing condition.	
	Miscellaneous	Acoustical	Supersonic energy, capable, for ex., of emulsifying mercury and water, may be considered a processing condition. Audible frequencies affect human output and hence come under working conditions. Many audiometers, etc.; few industrial.		
II PROPERTIES	1. Physical	Mass	Industrial recording and registering scales, etc.	Control usually indirect, **speed** being in most cases the controlled factor	Ordinary indicating balances and scales excluded.
		Density	Continuous indicators and recorders	Usually control of **flow or ratio.**	A.S.M.E. classifications of methods can apply to primary elements of industrial instruments for both of these objects.
		Viscosity	Mostly testing instruments	Usually control of **composition**	
		Calorific value	Recording calorimeters, etc.	Usually control of **composition**	
		Color	No strictly industrial **measuring** instruments, but	Automatic sorters, graders, etc. with photometric primary elements.	
		Melting point Boiling point, etc. Mechanical— Tensile strength Elastic limit, etc. Hardness etc	Few strictly industrial instruments. Most commercial instruments are **testing** instruments.		
	2. Chemical	Alkalinity, pH, etc. when considered as properties rather than composition	Conductivity cells, etc. connected to electrical ind. & rec. inst's	Controlling potentiometers, etc.	
	3. Electrical	Resistivity, permeability, etc.	No strictly indust'l though many **testing** instruments.		
III COMPOSITION	1. Physical (mech'l mixing)	Proportions, positions of ratio valves, dampers, etc.	Position indicators Special flowmeters Special recording scales	Automatic poidometers, etc. Most control systems are indirect: by flow, temperature and other processing conditions.	
	2. Chemical (compounding)	Analysis	Differential flowmeters, electrical remote indicators		
IV SIMPLE MAGNITUDES	1. Linear	Length, thickness, etc. Area	Mech. and electr. indicators and registers. Planimeters	Thickness control by roll pressure control, etc. Control of length in continuous processing is speed control.	
	2. Angular	Revolutions Angular position	Rev. counters Position indicators		
V SIMPLE QUANTITIES	(There can only be one group in this class **numerical** quantity)	"Number of—" "Production" "Traffic"	Mech., electr. and photoelectric counters, registers, totalizers, etc. For **rate** see I, 8.	Most forms of packaging machines and counting-loaders are not industrial instruments	
VI MISCELLANEOUS	1. Vibration	Frequency Amplitude	Vibrographs, vibration recorders, seismographs, etc.		
	2. Acoustical	Intensity, etc.	Audiometers, noise recorders, etc.		

Industrial instruments are devices of rugged construction and practical utility, for measuring or controlling—
1. The ten measurable processing and working conditions;
2. Various physical and chemical properties;
3. Physical and chemical composition; or
4. Miscellaneous other factors, conditions, quantities or magnitudes.

It is by no means final: properties now measurable only by laboratory instruments will sooner or later be measurable by industrial instruments. The question "what are industrial instruments?" seems to require modification to "which are the industrial instruments today?"

Table I represents a systematic classification along the line outlined above. It leads to a tentative definition:

Industrial instruments are those which automatically measure, record or control, for the One Best means (instrument) of controlling conditions, and by correlate and conscious correlation, by a constant search for the appreciation of the principle that *before a condition can be controlled it must be measured.*

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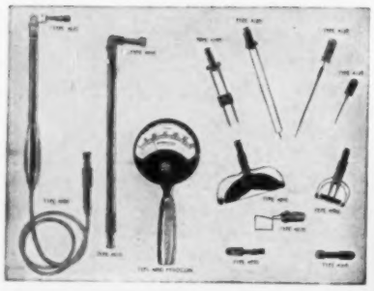

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particularly the educational market, for every large school is a user—the field of automatic timers. In this old and large "language circle" the term "automatic-reset" refers to a type of mechanism or to the particular function of such mechanism. *This is a fact*—or rather two facts: a situational fact and a statistical fact.

Now then, shall we or dare we "adopt" this old-established term to denote a radically different type of mechanism and a radically different type of function? This has not yet been decided for all the language circles of Instrumentation. It should not be decided by one Instrumentation circle for all Instrumentation circles, but it should be decided by the Facts and by the Weighting Factors.

One of the other facts (a second statistical fact) may perhaps turn out to be a twenty-to-one ratio of automatic-reset timers to modern temperature and other controllers which automatically accommodate the supply to the demand.

One of the weighting factors may turn out to be that an occupational language-circle, overlapping the general field of Instrumentation to a small but important extent, has been using a term denoting this function—perhaps the language circle of electrical engineering and perhaps the term "droop correction" or "automatic droop corrector."

Other facts will turn up—*all* the relevant facts will turn up—when they are dug up by methodical research. Other weighting factors will turn up—when they are discovered by the application of the inductive and deductive processes and other headaches of Methodology. Then, all the statistical and other facts, and all the discoverable weighting factors, will arrive by themselves at the logical decision.

This example of how to deal with one particular term has not mentioned Scientific Classification. But this side of Methodology was there all the same. And if this particular case were to be worked out completely, it would be seen that the solution would be based on procedures and processes that had led to "collectively-exhaustive categories" as well as to the more familiar "mutually-exclusive categories."

In fact, the way to go about this whole undertaking is to classify the terms themselves. No, not to list them all. That is impossible with any language. No dictionary is ever complete—not even a glossary pertaining to one sport or one trade or one profession. The job is to get up various lists of collectively-exhaustive and mutually-exclusive categories of terms. Different methods or schemes will produce different lists. Most of these lists will meet the all-important requirement of being collectively exhaustive because it is an easy requirement by itself. For example, the whole universe being divisible into "concrete" and "abstract" we can have:

1. Terms pertaining to things (names of tangible objects)
2. Terms pertaining to abstract entities

Since various eighteenth-century French scholars first tried it (and perhaps since ancient times) many men have worked out many schemes for arranging all the words of a language—or of *any* imaginable language—into collectively-exhaustive and mutually-exclusive categories. Surely a number of these schemes can be applied to the language of Instrumentation! Surely several of these schemes will each be suitable as a permanent building, so that every future candidate-word will be immediately assigned to the entrance-examination of one room (category) and one room only; and so that if it passes it will be admitted into the entire building—into the language of Instrumentation!

That is not a one-man job.

This discussion, being a one-man job, does not attempt to lay down *the* terms, but it may set forth underlying considerations and mention some already-surveyed areas.

Many individual categories have suggested themselves: terms denoting physical functions, terms denoting abstract relations, terms pertaining to relative degree, or to time and time effects, or to dimensions . . . even the category reserved for terms pertaining to classification!

But there are numerous easier jobs to be done in the way of classifying the things themselves—the "instruments"—in order to name them correctly.

Hopelessly impossible as is the task of writing down an exhaustive list of names of kinds of instruments, or even of methods, it is possible to formulate basic schemes, any of which would be exhaustive for all practical purposes. The exhaustiveness may depend on definitions, as in some of the following examples:

(A)	(B)
1. "Scientific"	1. "Laboratory"
2. "Industrial"	2. "Plant"
3. "Domestic"	3. "Field"
4. "Universal"	4. "Universal"
(C)	**(D)**
1. Contact	1. Local
2. Distance	2. Telemetering
(E)	**(F)**
1. For measuring invariables (e.g. Metrology)	1. Self-operating (incl. direct-writing)
2. For measuring variables	2. Relay (using auxiliary power)
(G)	**(H)**
1. Indicating	1. Portable
2. Maximum- or minimum-registering	2. Board- or wall-mounted
3. Recording	3. Built-in
4. Metering	4. Convertible
5. Controlling	
(I)	**(J)**
1. Single-point types	1. "Ready-to-use" or "factory calibrated"
2. Selector-switch types	2. Requires calibration

Some of these schemes are defective, of course—particularly (A), which suffers from acute "user-itis": a vest-pocket micrometer or pressure gage or voltmeter or hydrometer or thermometer would belong under 1, 2, 3 or 4 according to the occupation pursued by the wearer of the vest. Scheme (B) suffers from a different disease which we might call "usage-itis": it depends too much on the meanings which a reader attaches to the names of its four fundamental categories.

On the other hand, most of the names of the categories in examples (G), (H), (I) and (J) are "tight definitions"—for purposes of classification, at least. A particular instrument will usually belong in one category, and in only one. Usually but not always, for two obvious reasons: (1) the commonest current terms are nearly always the loosest; (2) newly-coined terms become ambiguous when they pass into the vernacular.

However, by an old methodological trick, some "perfect" general-purpose classifications of *things* are those made up of *quantitatively graded* categories defined by arbitrary intervals. Examples in the field of temperature instruments:

(K)	(L)
1. Limits of practicable ranges extend from 0 °Abs. to 100 °Abs.	1. $4.99 or less
2, 3, 4, etc. Similarly defined.	2. $5.00 to $99.99
	3. $100 to $499.99
	4. $500 or more

There may be said to be three broad rules governing the classification of *things*:

(1) The narrower the scope of interest, the easier it is to meet the two principal requirements. See examples (C) to (L).

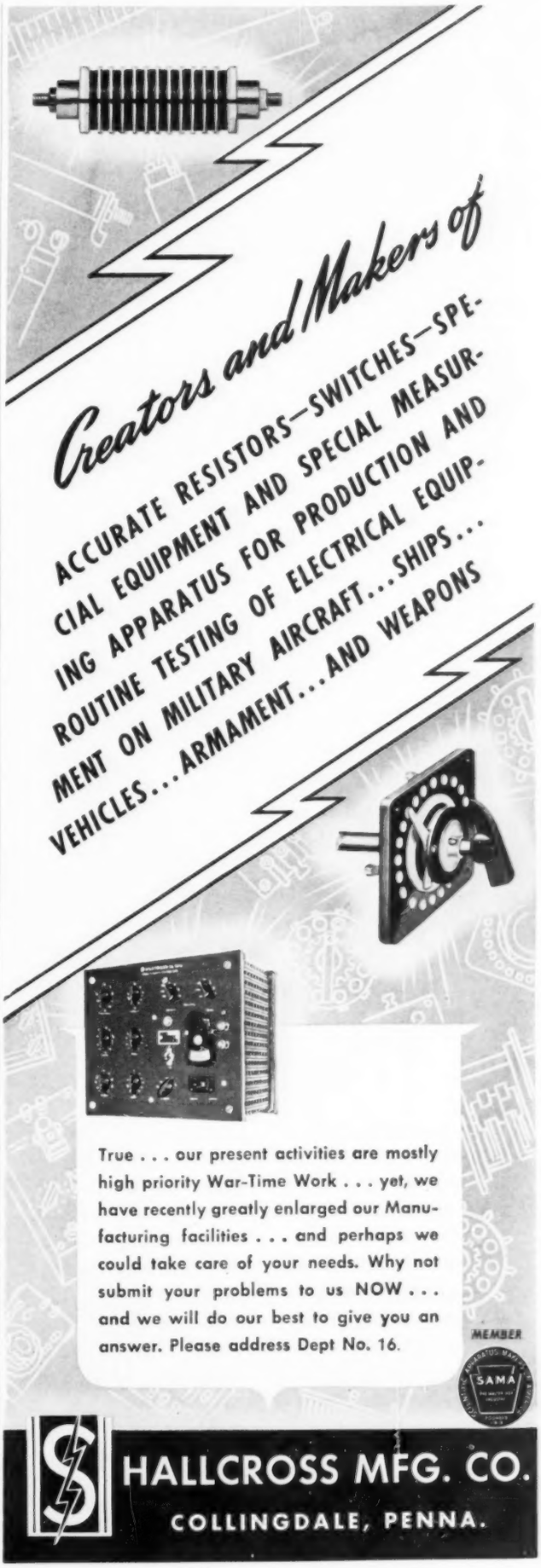
(2) The fewer the prime divisions, the easier. Hence, the easiest scheme is a simple "either-or" bifurcation, like "abstract and concrete," "live and dead," "subjective and objective"—or like examples (C),(D),(E),(F),(I) and (J).

(3) Within each prime division, likewise, the easiest scheme is a simple "either-or."

Rational classifications are particularly helpful with regard to terminology and symbols because they probably do more than any other method to prevent confusion. If a thing belongs to the "dolly" category it will not be given a name pertaining to the "marble" category. And if a term belongs to the "dolly" category it should not be adopted to denote a thing or an abstract entity belonging to the "marble" category. Laugh if you will at the Latin names of Natural History but those eighteenth and nineteenth century scientists certainly showed us the way to the science of correctly naming things.

The best thing about scientific classification as the foundation of logical terminology in a scientific-and-industrial field such as Instrumentation is that each scheme worked

(Continued on Page 320)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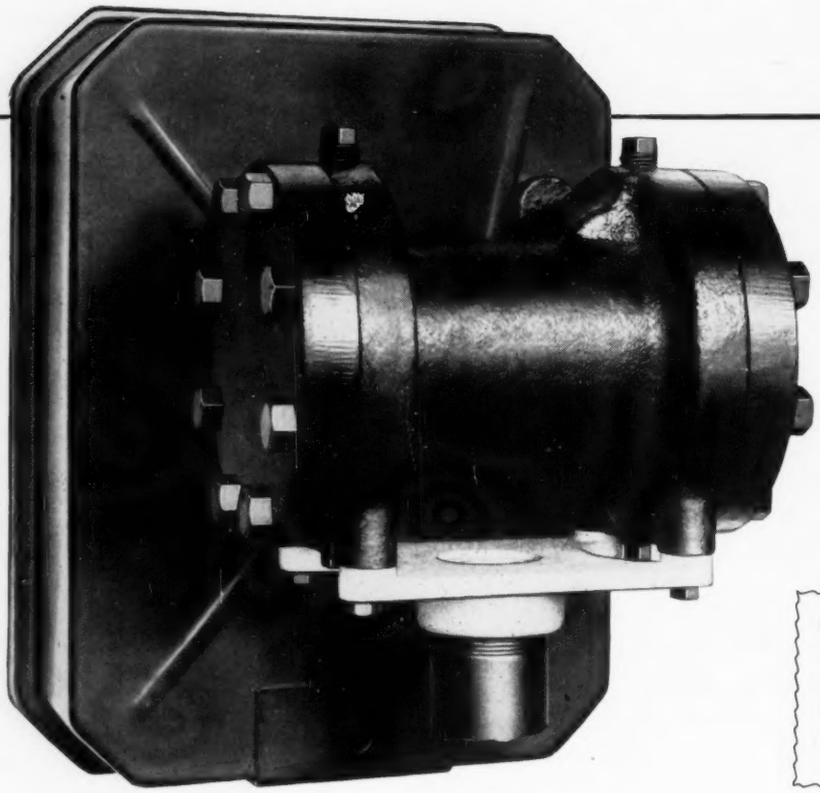

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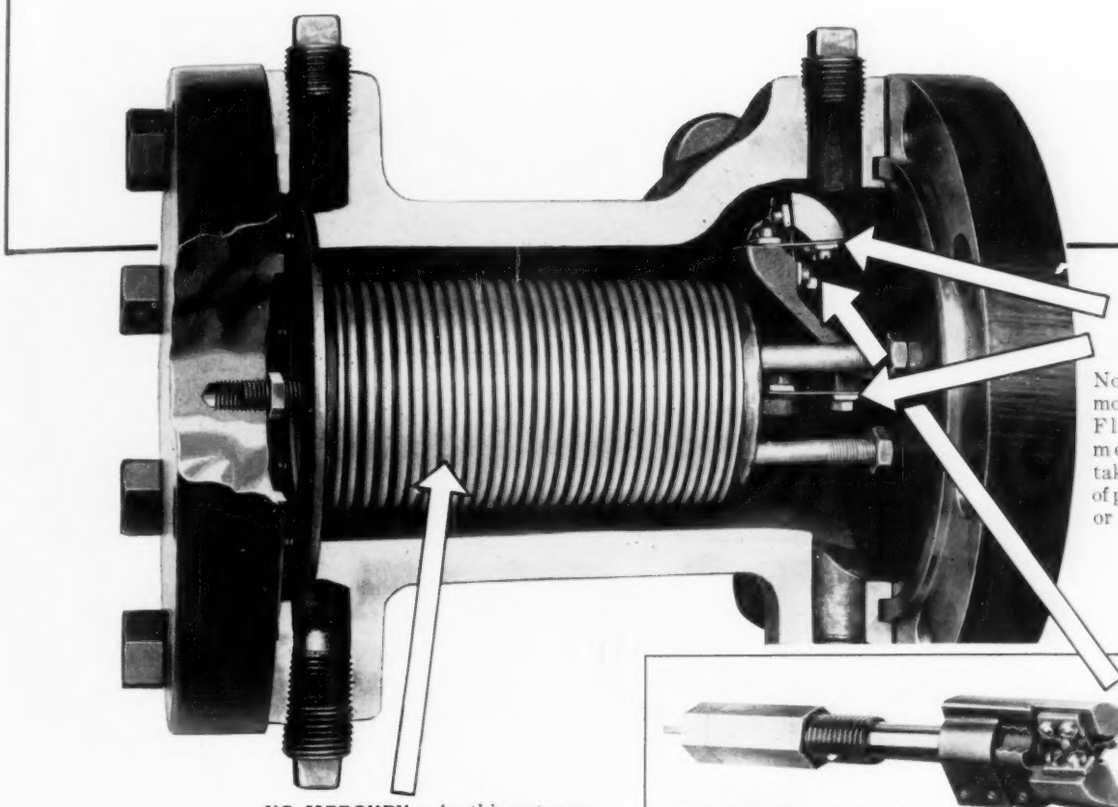

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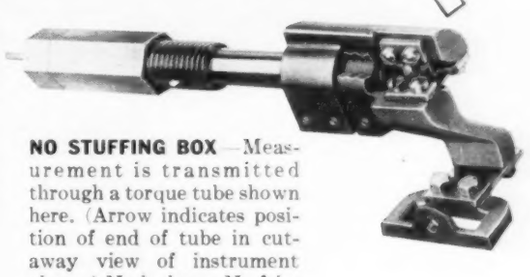
No friction, lost motion, or wear. Flexible flat metal strips take the place of pivots, springs, or bearings.

NO MERCURY—As this cutaway photo shows, differential pressure is measured by a metal bellows. No contamination—no worry about theft or "blowing".



NO STUFFING BOX—Measurement is transmitted through a torque tube shown here. (Arrow indicates position of end of tube in cutaway view of instrument above.) No leakage. No friction. No lubrication!

give free access to interior mechanism without breaking pipe connection.

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Communication Flight-testing Production Instrument-testing

Vol. I, No. 3 GUEST EDITOR: F. N. M. BROWN August 1942

WHAT'S AN ENGINEER?

By F. N. M. BROWN

Chairman, Department of Aeronautical Engineering, Notre Dame University, Notre Dame, Indiana

QUITE frequently the undergraduate student at an engineering college—and occasionally the graduate—has a question that is almost never answered to the satisfaction of the questioned. It is asked a hundred times a year in as many forms. It is, "What is an engineer; what will I be when I am through; what will I be doing . . .?"

Answering such a question is of the same order of difficulty as describing a giraffe to an Eskimo. Two reactions are common: dissatisfaction and disbelief; the first in response to generalization and the second to detailed description.

Mr. N. Webster leads off with "an inventor; a plotter; one who designs," and the reader instantly substitutes his own synonyms, which may be anything at all, but are usually "crackpot; Black Hand (complete with dagger); dressmaker."

Noah Webster's second try is "one versed in, or who follows as a calling or profession any branch of engineering." This is no help at all if one ignores the subtle humor in the implied distinction between being "versed in" and "following as a profession."

A third go at it (omitting some dilly-dallying with the Brotherhood and with British usage) which is perhaps not intended to apply to members of the engineering profession, is the best of all. It is, "one who carries through an enterprise by skillful or artful contrivance." On close examination even this one leaves much to be desired. One has only to substitute "sewer project," "bond issue" or "horse trade" for "enterprise" to make the shortcoming clear.

This individual soon recognized the indicated inadequacy of definition and decided that the only profession Mr. Webster ever defined to the satisfaction of all concerned was that of lexicographer. He learned, too, that while two lexicographers might define "engineer" in practically identical, and inadequate, phrases, two engineers would turn in two adequate, and unrelated, definitions. This impossible state of affairs is the result of (as in the case of the giraffe) over-generalization on one hand and over-specification on the other.

More than thirty years ago I heard a definition that seemed to strike a middle ground. I have tried to improve the language and failed; I have tried to make it more general or more specific and I have failed. I give it to you as that tough old Dakota pioneer gave it to me: "An engineer is a man who thinks up a useful machine, makes it work, and then hires a clerk to make it pay."

From *Who's Who in Engineering* we learn that our Guest Editor's full name is Frank Newton Mithery Brown. He was born near Jamestown, North Dakota on September 16, 1902; and received his engineering education at the University of Michigan where, in 1928, he obtained the degree of Bachelor of Science in Engineering. After a few months as aeronautical engineer with the Ford Motor Co. in 1928, he served two years as Assistant Professor of Aeronautical Engineering at the University of Michigan. From 1931 to 1933 he was Technical Editor with the U. S. Army Air Corps and during this period he obtained his Master's degree. From 1933 to 1935 he served as research engineer attached to the dirigible *Macon*. Then, after a few months as installation engineer with the Allison Engineering Co., came his appointment in 1935 as head of the department of aeronautical engineering of the University of Notre Dame. He is the inventor of the photographic space-time recorder described in this issue; also of a capacity pickup for a torsional vibration indicator and recorder; and of instrumentation for damping capacity evaluation. He organized and developed the aerodynamics and internal combustion engine laboratories at the University of Notre Dame. He is an Associate Fellow of the I.A.S., a member of the Committee on Aeronautical Engineering of the S.P.E.E., and active in other societies.

Space-Time Recorders in Airplane Landing Gear Testing Laboratories

By F. N. M. BROWN
Chairman, Department of Aeronautical Engineering, University of Notre Dame

IN a way common to the appearance of all instruments, the space-time recording instrument made its appearance in the environs of the landing gear drop testing rig. Human perception had proved to be either inadequate or too costly. In the case of landing gear drop test human perception was simply inadequate. The whole action including a couple of rebounds took place in the space of one half of a second. In that time there were a number of phenomena to be observed and set down. To wit: One, was the free drop really free or had friction in the rig made good old G over into a pallid x? Two, at what instant (to be used later as a sort of zero hours G.C.T.) did the tire make contact with the floor of the rig? Three, what were the velocities and the accelerations of the sprung and unsprung masses, respectively and in fine detail, after contact? Four, what was the net energy absorption of the system? Five, was the phasing of tire and taxi element period going to make the pilot post during a landing? and Six, well, Six was to prove it to the Engineering Branch.

It is somewhat surprising, in view of the last item, that Static Test clung to the old ways so persistently. Practically anyone knows that a full half-minute is required to think "Engineering Branch" together with the deserved adjectives, let alone convince them of anything.

The old ways, incidentally, seem to have been to see if some part of the strut-wheel-tire combination could be broken in the drop test rig and, if it could not, to put the landing gear on an airplane and see if some part of that could be broken, preferably by a pilot with defective depth vision. If Static Test did not have luck in either venture the gear seems to have been approved and it then rolled off the assembly lines practically by the half dozen.

DePort, a civilian engineer with the Matériel Division, while perhaps not the first to sense the need for instrumentation in the field, was the first to do anything concrete about it. His instrument was used at Wright Field in 1928. An identical instrument was purchased by Bendix in 1929. In this instrument the vertical motion of the sprung and upsprung masses is transmitted through hard wires over pulleys to spring-loaded drums fitted with stylus-sensitized paper, in such a way that fall or rise of either mass causes rotation or counter-rotation of its particular drum. The time element is imposed by a whisker head rotating at synchronous speed (1800 r.p.m.) in the plane of two diametrical elements of the drum. The whisker head supports seven whiskers of styli arranged radially at intervals of forty-five degrees. The omission of the eighth whisker aids in track identification. The time interval between the marks made by the whiskers on the paper covered drum is 1/240 of a second. During the drop the drums are moved axially at constant speed to spread the record and prevent overlapping.

The instrument used at N.A.F. was developed at about the same time and also uses a mechanical linkage. In this case, however, a true space-time diagram is drawn directly by the instrument. The record paper is transported horizontally at constant speed (220 inches/second) and pencils or styli move in vertical guides. The styli are connected to and actuated by closed loops of extra-flexible cable attached to both sprung and unsprung masses. A complex pulley system is employed to direct the closed cable loops.

In the Buffalo plant of the Curtiss-Wright Corporation a device resembling in principle the DePort recorder is in use mainly for the drop testing of the complete airplane. In this device two record paper strips are drawn past the rotating stylus head by the falling sprung and unsprung masses through a simple cable and pulley arrangement. The stylus head is driven by a 1500-r.p.m. synchronous motor and carries four styli spaced at ninety degrees. The time interval between marks on the record is 1/100 of a second.

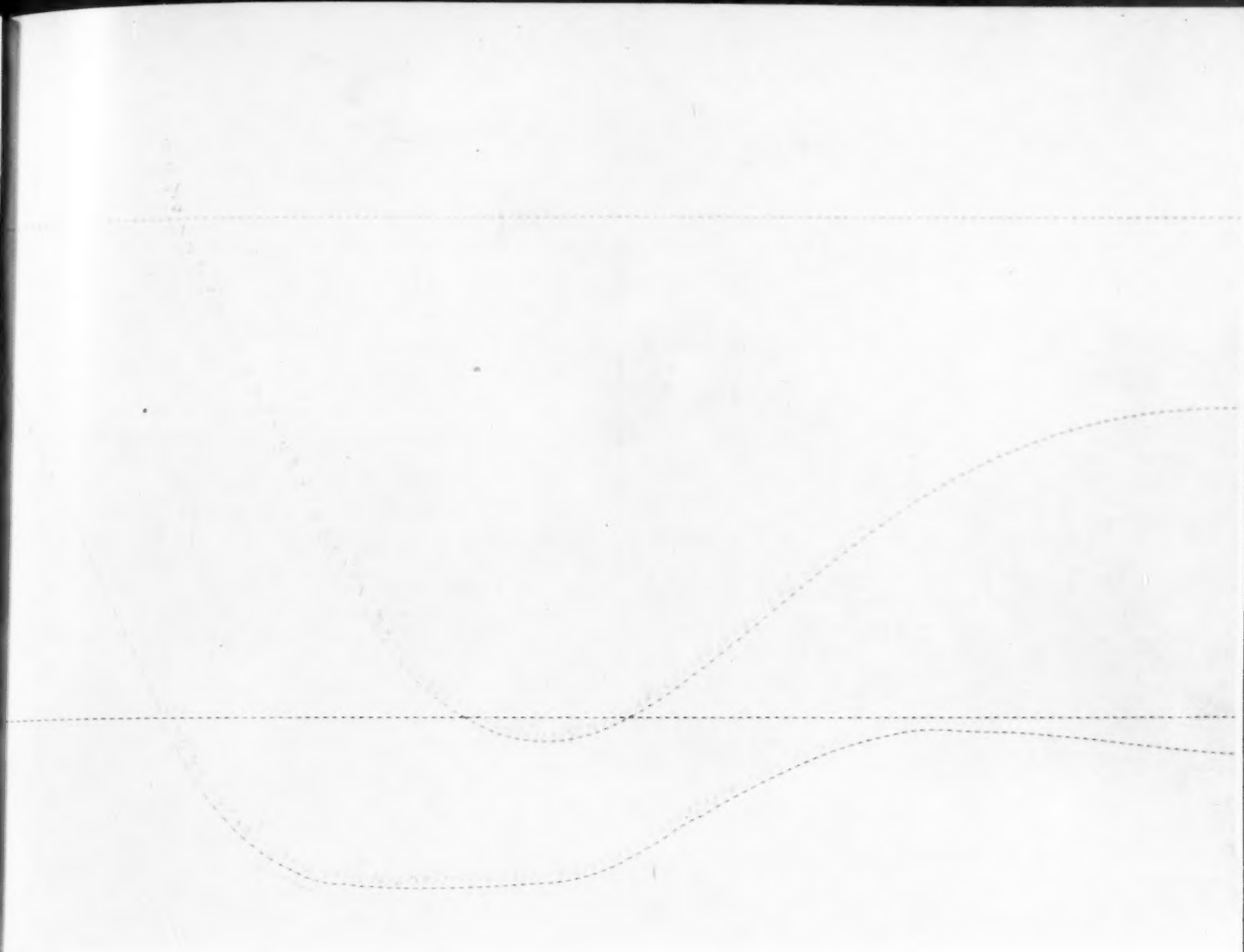
In the Aircraft-Automotive Division of the Cleveland Pneumatic Tool Company a device designed and developed by J. F. Wallace has been in use since 1931. Herein the loads are determined directly by means of a magnetic strain gage within a dynamometer ring mounted between the main sprung mass and the upper part of the strut. In addition, slide-wire potentiometers are arranged between the upper and lower parts of the strut and between the wheel and the jig. All three magnitudes, and deflection of the ring, the relative motion between the two parts of the strut and the deflection of the tire, are then represented on the photosensitive element of an oscillograph.

Fig. 1. Photographic Space-time Recorder.

In 1938 the Matériel Division procured from the Fairchild Aerial Camera Corporation a photographic space-time recorder that had been designed under the supervision of Ralph Middleton, a Matériel Division engineer. This device is simply a special camera equipped with a long focal length lens, a device to transport the film laterally during the drop and a disc type shutter in front of the lens to provide accurate timing. The traces on the film are made by high intensity lights attached to the sprung and unsprung masses.

In the fall of 1936 a conversation with C. V. Johnson of Bendix led the author into an investigation of the possibilities of a simple inexpensive photographic space-time recorder. Eighteen months later, the first recorder was delivered to the Bendix Products Division, to be followed by another, somewhat improved, in 1941. The original recorder is now the property of the University of Michigan. The instruments are identical in principle.

This recorder is provided with a twenty-inch lens which may be racked in or out to provide scales from 1/10 to 1/2 of full size. Behind the lens is a two-blade barrel type shut-



Actual Size Portion of a Record Obtained with the Photographic Space-time Recorder.

ter driven from a synchronous motor through a gear increaser at 7200 r.p.m., thus providing 14,400 interruptions per minute. The photo-sensitive element is mounted on a drum nine inches in diameter and twelve inches high, which is driven by a synchronous motor through a gear reducer so that the actual speed of the photo-sensitive element is 14.19 inches per second. The photo-sensitive material used is ordinary photostat paper. The photographic trace is provided by high intensity lights (ordinary five cell flashlight bulbs) attached to the sprung and unsprung masses or, for that matter, to any portion of the system that it is found desirable to investigate.

The first three space-time recorders mentioned above, the DePort, the N.A.F. and the Curtiss-Wright, depend on mechanical linkage for the transmission of the space element from the falling mass to the record paper. Of these only the first is able to record the rebound phenomenon. All are subject to an inertia error which appears to be of the order of $0.1G$ to $0.15G$. The error is serious mainly because of its unpredictable character.

The fourth recorder mentioned, that designed by J. F. Wallace, was definitely more than a stride in the right direction. Herein the inertia error was largely if not completely eliminated by reducing the travel of the actuating element from feet to a matter of perhaps 0.005″. A considerable sacrifice of simplicity and the introduction of highly sensitive and necessarily delicate instrumentation are the only prices paid for excellence of results.

The Matériel Division recorder has none of the faults of the mechanical or electrical transmission instruments discussed above. The inertia error is, of course, completely eliminated. The set-up time is minimum and the instrument may be used under almost any circumstance wherein a space-time record is desired. Only the following points of criticism are offered. First, the film transport is not positively synchronous, especially during the first part of the record; second, processing time of the film and print are excessive; and third, both original cost and operational cost are high.

The recorders now being used by the Bendix Products Division and the University of Michigan were designed by the author with certain definite ends in mind. These ends were: one, that the original cost of the instrument, exclusive of design costs, should be less than half the cost of other recorders and, two, that the instrument be so simple to operate and the processing and reduction of the record be so easy as to greatly reduce the time (and so the cost) between the drop and the final reduction of the data. These ends are realized.

Reduction in original cost was achieved mainly by the use of the drum instead of the film magazine and horizontal transport system. Simplicity of operation and processing of the record as well as reduction of time between drop and drafting board was accomplished by the use of photographic paper instead of film. A seasoned operator can place the completed space-time record on the drafting table within fifteen minutes from the time of the drop. Final reduction of the record requires less than an hour.

It is the author's conviction that the drum type photographic space-time recorder is superior to all other types in the matter of original, operational, and record reduction cost. Its accuracy is at least equal to that of any other recorder. Finally, it is not bound to any particular jig or installation but may be used under almost any circumstance wherein a space-time record is desired. In short, a Static Test instrument that Engineering cannot discredit.

Glider Instrumentation

By R. S. EIKENBERRY

Ass't Professor of Aeronautical Engineering, University of Notre Dame

MANY people seem quite astonished to discover that a glider is equipped with any instruments at all. As a matter of fact, many training gliders of a few years ago were completely devoid of instruments. However, modern high-performance sailplanes have more complete panels than many airplanes; and even the simplest trainer usually now has at least an airspeed indicator.

Due to the small number of gliders in use in this country (only 168 in October 1941) there has been little development of special instruments. The glider constructor has consequently found it difficult to obtain entirely satisfactory equipment. Standard airplane instruments are rarely suitable because they are designed for different operating conditions. For instance, the lowest reading on an airplane airspeed indicator is just about the usual cruising speed for a glider. Vibration is one of the instrument-maker's worst headaches in the case of an airplane; the complete lack of vibration in a glider is almost as bad because it results in sticking instruments.

The only essential instrument for a training glider is the airspeed indicator. However, even training gliders of modern design are capable of soaring flight, which is the real desire of every glider pilot. For successful soaring a rate-of-climb indicator is essential and an altimeter is very desirable; so we may say that the three fundamental glider instruments are the airspeed indicator, rate-of-climb indicator, and altimeter.

The Airspeed Indicator: Airplanes universally use the Pitot-static indicator. This consists of a sensitive pressure gage calibrated in miles per hour which measures the pressure difference between a Pitot tube and a static tube which are mounted in the undisturbed air stream. This pressure difference is equal to the dynamic head $\rho V^2/2$. Since the pressure varies with the square of the speed, the slow speed end of the scale is much compressed. In fact, few airplane indicators are graduated below 40 m.p.h. Since the usual cruising speed of a glider is in the 35 to 45 m.p.h. range, it is seen that such an instrument would be practically worthless for such use. It might be thought that the solution is a more sensitive indicator; but the pressures produced at these low speeds are so small that an accurate and reliable instrument can hardly be produced at a reasonable cost.

The most common solution of the airspeed indicator problem is the substitution of a Venturi tube for the static tube. By this means it is possible to more than double the pressure difference produced at a given speed, and a satisfactory instrument can be produced by re-calibrating the dial of a standard airplane instrument.

Another type of instrument which sees some popularity and is perhaps deserving of more attention is the pressure plate indicator. This is available commercially in the form of a little windmill wheel which is rotated against a spring by the airstream. A scale of m.p.h. is marked around the edge. A home-constructed type sometimes seen has a small flat plate protruding from the fuselage in front of the cockpit. As the wind pressure pushes it back against a spring, a pointer moves along a vertical scale which may be placed on the panel in the cockpit. Instruments of this type, if properly designed and constructed, are probably more rugged and dependable than any other and are much cheaper. Their main disadvantage is that they must be located in disturbed air near the fuselage, so that each installation must be calibrated.

Rate of Climb Indicator: The procedure in soaring flight is to circle in areas of rising air so as to remain in them a maximum length of time and fly straight through areas of descending air so as to remain in them a minimum length of time. Since these air currents are not visible, they can be detected only through their influence on the glider; that is, whether it is rising or sinking. Once the pilot is a few hundred feet above the ground he can no longer detect small rates of ascent or descent, so an instrument must be provided to furnish this information. Such an instrument should indicate rates of ascent and descent as small as one or two feet per second and as large as 25 f.p.s.; and in order that the pilot will not fly clear through a small area of rising air before detecting it, the indication should be practically instantaneous.

The usual type of instrument consists of a sensitive pressure gage measuring the pressure difference between the outside air and a small insulated container. This container communicates with the atmosphere through a small leak. Under conditions of uniform ascent or descent, this pressure difference is proportional to the rate of change of altitude. However, it is obvious that this pressure difference will not appear until a considerable change of altitude has occurred; so some lag is inevitable. Reducing this lag means reducing the pressure difference necessary to produce a reading, which in turn means that the indicator must be more delicate and expensive. An entirely satisfactory instrument of this type is so expensive as to be entirely out of reach of most glider pilots.

One inexpensive and simple solution is to use a manometer as the indicator. An instrument with a degree of sensitivity and a lag about equivalent to the usual commercial

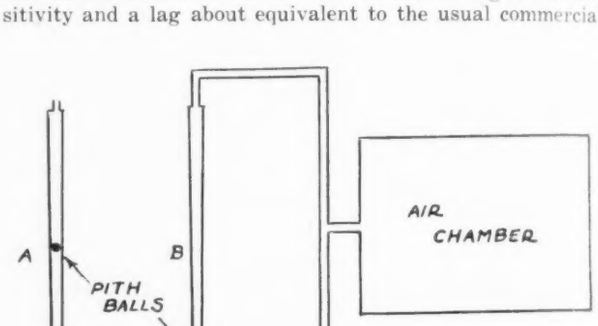


Fig. 1

types may be made in this way for a total cost of two or three dollars. The main disadvantage is that the reading is affected by accelerations; in a 60° bank, for instance, it is cut in half.

Within the last few years, an entirely different type of climb indicator has found increasing favor among glider pilots. This instrument is shown schematically in Fig. 1. It is really a flow indicator rather than a pressure indicator, and therefore has little lag. It consists of two tapered tubes containing small pith balls and connected to an insulated vessel. When the glider rises, the external pressure drops below that in the vessel and the pith ball in tube *A* is lifted off its seat. The greater the rate of ascent, the greater the flow out of the vessel and the higher the ball is raised in the tapered tube. In descent, the action is the same except that the ball in tube *A* is held on its seat and that in tube *B* is raised. Since the pressure difference required to raise the ball is extremely slight, only a very small change in altitude is required to produce a reading. The writer has seen instruments of this type which would give an indication when raised only four or five feet. This type of instrument is not only superior to the ordinary type with respect to sensitivity and lag, but can be produced much more cheaply. It is inferior to others with respect to accurate calibration, but this is not so important to the glider pilot.

Altimeter: Until recently, there were available only two general types of altimeter; the standard and sensitive types. The standard type is not satisfactory because its

small scale division is two hundred feet. In ordinary airport flying it gives only a rather rough figure on altitude. The sensitive type reads down to ten feet and is quite satisfactory but the cost is far beyond the reach of most glider pilot.

Recently, however, a new type has appeared on the market which is ideal for gliders. It may be called semi-sensitive and reads to fifty feet. Its cost is also reasonable.

This completes the primary flight instrument group, and nothing else is really necessary for the average pilot. However, the pilot of a high-performance sailplane who wishes to obtain the maximum results in the direction of altitude and distance soon finds that he must throw off the limitation imposed by the cloud base; that is, he must be able to go up into the clouds. For this purpose some gyroscopic instrument is necessary in order that the pilot may keep himself oriented when flying blind. A turn indicator is ordinarily used for this purpose. It is a gyroscopic instrument which indicates the rate of rotation of the glider about its vertical axis. A lateral inclinometer is usually mounted on the same dial. This indicates whether the resultant of the weight and centrifugal force is acting perpendicular to the wing. Since this is the case both in straight flight with wings level and in turning flight with the wings banked at the proper angle, this bank indicator is not sufficient of itself and must be used in conjunction with the turn indicator.

The gyroscope of the turn indicator is ordinarily driven as a little turbine by an air jet. The pressure difference required to operate it is obtained from a Venturi tube mounted in the air stream. Due to the slow speed of a glider, a much larger Venturi is needed than on an airplane; it may become a fairly considerable item of drag. Also, on high flights, difficulty may arise due to ice forming in the Venturi. What is badly needed for glider use is an electrically driven turn indicator. So far as the writer knows, no such instrument is available in this country, although they are in some others.

It might be pointed out in passing that the mere installation of blind flying instruments is not sufficient: the pilot must be thoroughly trained in their use before he can safely tackle the inside of a cloud. More than one pilot has been forced to resort to his parachute because he neglected this point.

A compass is commonly mounted in sailplanes intended for cross-country soaring. A cheap airplane compass or even an automobile type is quite satisfactory, since the continuous circling makes accurate navigation impossible.

Other instruments, such as clock and thermometer, are sometimes mounted. These are not at all essential, and are easily and cheaply available. For contest flights, a barograph is required to record duration and altitude. A satisfactory instrument has been available for about thirty-five dollars.*

In conclusion, we may say that the proper instrumentation of a glider requires the same instruments as are found in an airplane (engine instruments excepted); but due to the different operating conditions and requirements, they should be specially designed. Few such special instruments are available at the present time.

*Word comes that the only company which made a $35 glider barograph has gone out of business.—M. F. Behar, Editor, *Instruments*.

The DePort Space-Time Recorder

By A. N. NORDGREN

Engineer, Bendix Products Corp.

PRINCIPAL aviation use of the space-time recorder is in laboratory drop testing of airplane landing gear shock struts, to give a comprehensive picture of the action of the landing gear in its function of limiting the deceleration of the test mass and preventing excessive rebound. One convenient and accurate recorder is the DePort space-time recorder.

The recorder unit, shown in Fig. 1, consists of two lightweight drums mounted with their axles horizontal and parallel. Endless wires make several turns around each drum and continue over pulleys at the top and bottom of the stationary uprights which guide the weight box. A mast on the weight box is attached to one of these wires, which causes the surface of the drum to follow the motion of the test mass. The wire to the other drum is attached to move with the axle to give a record of tire deflection. However, this can be used only when the shock strut is mounted vertically with the wheel on the axis of the strut.

Mounted between the drums in the plane of their axles is a vertical spindle turned by a synchronous motor at a constant rate of 30 r.p.s.

This spindle carries a head having eight small brass wires radiating from the center. These wires are equally spaced and as the drums revolve past the rotating head, marks are made on sensitized paper on the circumference of each drum at intervals of 1/240 second. The distance between these marks represents the distance the weight box or axle moves in 1/240 second. To prevent overlapping of the marks, the drums are moved longitudinally by a motor-driven screw while the record is being made. The drums move longitudinally at such a rate that a record is obtained of the travel of the test mass and of the axle from the time the weight is tripped to the third or fourth rebound.

Releasing the trip on the weight box automatically starts the drum carriage on the recorder unit. Two records similar

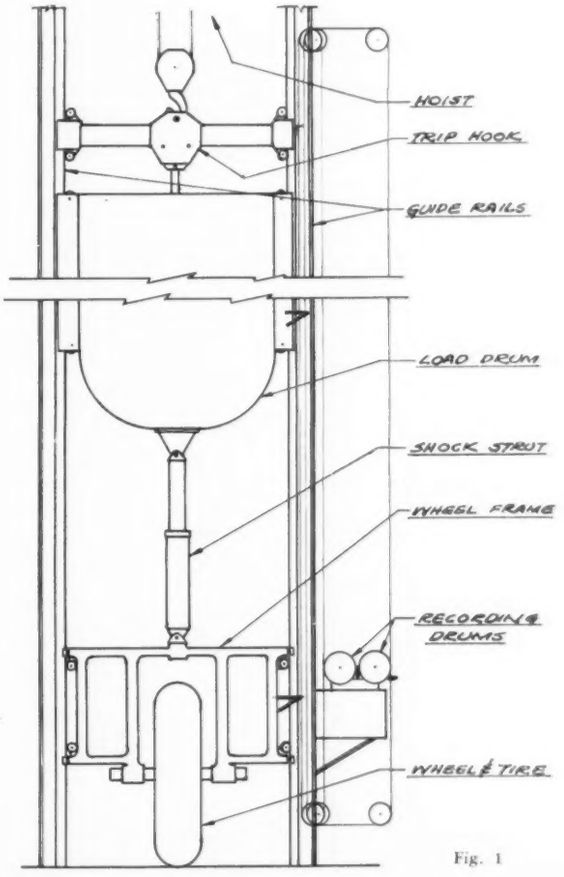


Fig. 1

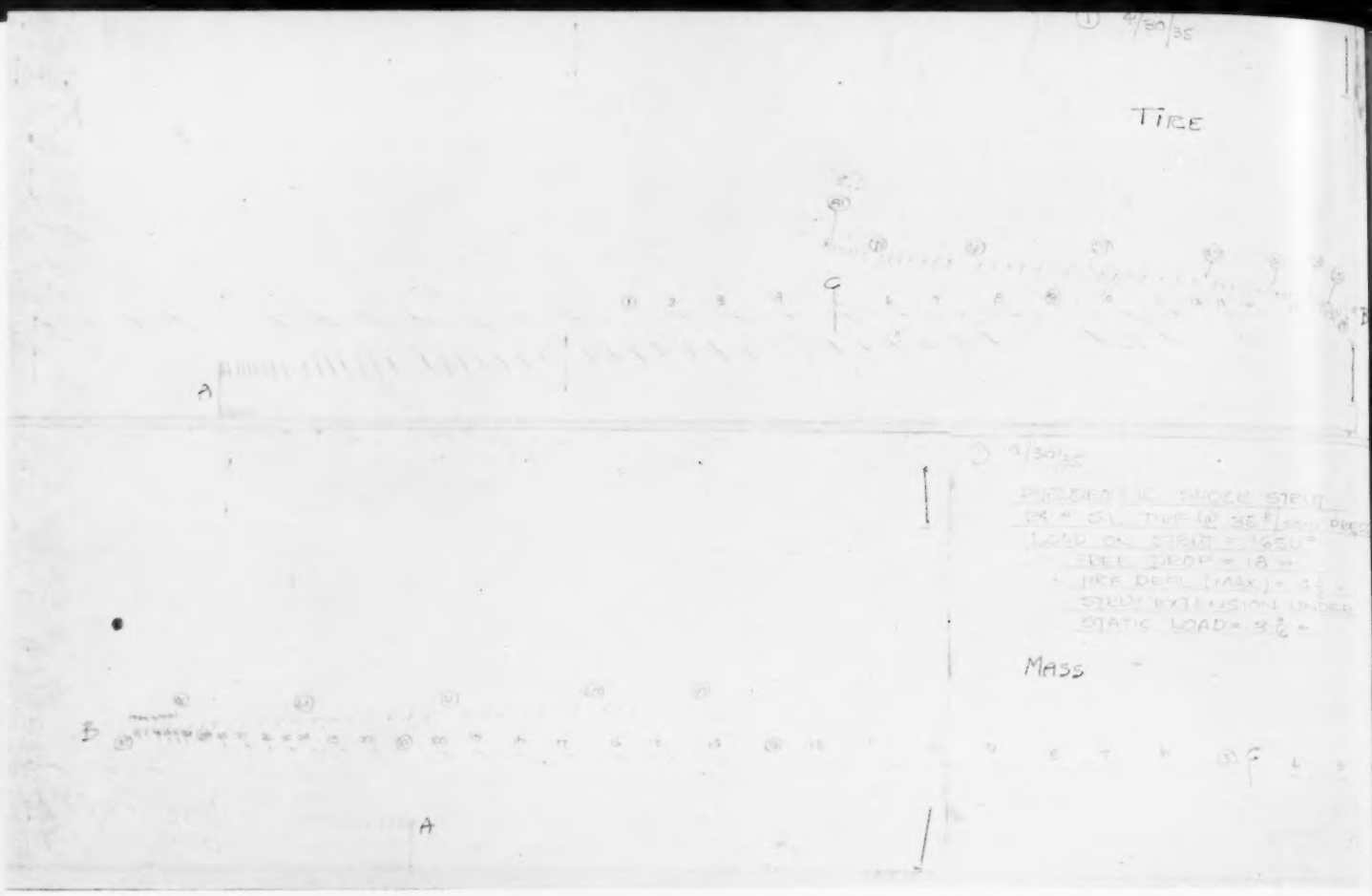


Fig. 2. (NOTE—These portions of records are reproduced approximately two-thirds actual size—Editor *Instruments.*)

to those shown in Fig. 2 are made simultaneously. Point *A* represents the beginning of the fall. Point *B* represents the point at which the rebound begins. The records shown in Fig. 2 were obtained in an 18″ free drop. The first 18″ of the record, from *A* to *C*, represents the free fall. The tire first contacts the ground at point *C* where the mass ceases to be falling freely and is being retarded by the tire and shock strut. Point *B* on the mass travel record is the lowest point of mass travel and, on the tire record, the maximum deflection. The mass rebound is measured from point *B* to the next inflection point. The tire rebound is measured from the point of contact *C* and represents the deflection of the tire or the distance the tire leaves the ground.

The marks are numbered from several marks before the point at which the tire contacts the ground to the end of the first rebound. It is advisable to remove one of the wires on the timing unit to form an evident blank on the records in order that the curves will not be displaced if a point is lost. The marks at the point of ground contact are numbered the same on both records.

Taking the center of these marks and plotting the distance from the ground contact point of the mass and tire, against time, we obtain curves of mass travel and tire deflection. Then, by subtracting the tire deflection from the mass travel and plotting from the zero movement line, we obtain the time stroke curve.

Mass velocity is obtained by graphical differentiation of the mass travel time curve; then by a similar differentiation of the velocity time curve, we obtain the mass acceleration time curve. Since the mass travel and strut stroke curves are plotted against time, we can arrive at the acceleration stroke relations.

Errors could be expected from this type of recorder due to the following conditions:

The marks on the record are not definite in location; therefore it is necessary, in transferring the points to the curve sheet, to locate the centers of these marks. This requires reasonable care by the operator to obtain satisfactory results. All points are measured from the ground contact line which eliminates cumulative errors.

The drums are moved longitudinally by the screw during the recording period and since the upper part of the loop of wire from the mass to the drum is longer than the lower part of the loop, some rotation of the drum towards the shorter section of wire could be expected. The decrease in recorded mass travel is less than 0.01% and since this reduction is uniformly distributed with time, the effect is negligible.

The inertia of the recording drum and guide pulleys suggests a possible source of error in the recorded mass travel. The maximum deceleration occurs during the period from tire contact with the ground to the lowest point of the mass travel. Considering this period and assuming that the drum peripheral velocity has reached the velocity of the test mass during the free fall, then as the mass is decelerated at an increasing rate an increasing tension force is created in the lower section of the wire which would elongate the wire, causing an added rotation of the drum. The mass deceleration, reaching a constant maximum, would produce no change in the relative drum movement, but as the deceleration is reduced, the tension would be decreased and the drum rotation would be reduced. The effect would be to record lower factors as the mass deceleration is increasing, record no change at constant deceleration, and to record lower factors as the mass deceleration decreases.

Calculating the moments of inertia of the drum, pulleys and wire, shows that a force of approximately one pound is required for each *G* change in acceleration of the drum. The corresponding increase in length of the wire between the drum and test mass is approximately 0.007″ per *G* change in acceleration. Thus for a 5 *G* change in acceleration the error in recorded mass travel would be 0.035, which is approximately 0.2% error in total mass travel. The effect on recorded deceleration is somewhat greater, and comparison with a space-time recorder not subject to this inertia effect shows that this error is in the order of 0.1 *G*.

The early model recorder described is limited in use, in that unless the strut is mounted vertically with the wheel on the axis of the strut, only a record of mass travel can be obtained.

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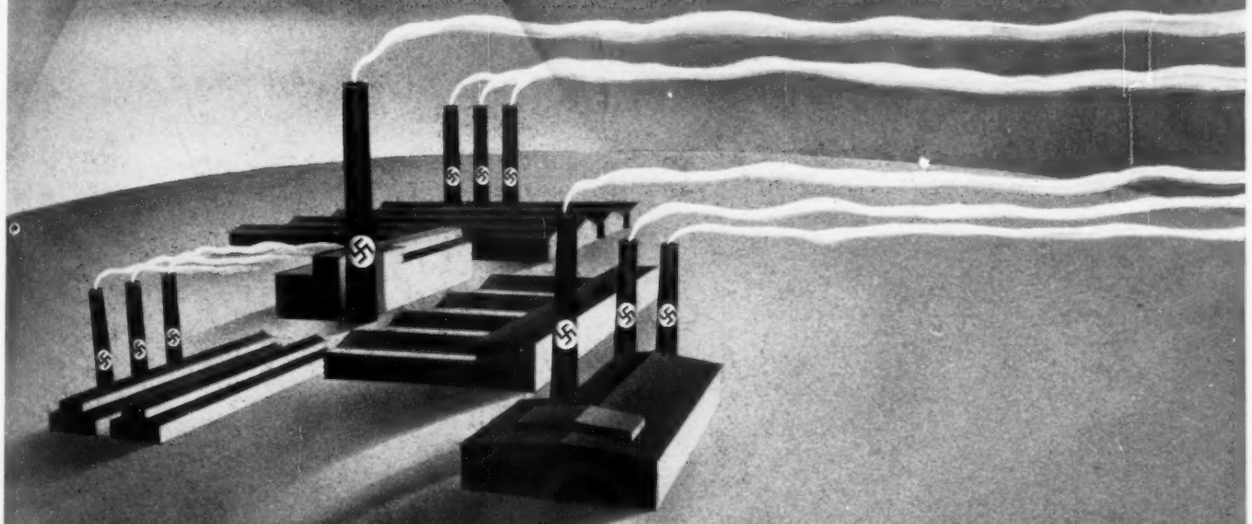

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Flow Bench Testing of Stromberg Injection Carburetors

By FRANK C. MOCK

Director of Aircraft Carburetor Engineering, Bendix Aviation Corp.

NOT the least of the advantages of the Stromberg injection carburetor which is in general use today on both commercial and military aircraft, is the fact that these complex, almost completely automatic units can be tested and adjusted with great accuracy, entirely separate from the engines on which they are to be used. All that is required is the relatively simple test equipment shown here. It is called a Flow Bench.

The duty of any carburetor is to mix gasoline with the air entering the engine, maintaining the proper fuel-air ratios for all conditions of engine operation. The fuel-air ratio for each engine operating condition is established by the engine manufacturer and must be strictly adhered to for satisfactory engine performance.

In most carburetors engine suction is used to draw or suck the fuel into the air stream. In the injection type carburetor, however, engine suction is used to control, but not to motivate, the flow of fuel. The volume of fuel flowing through the metering jets in the carburetor is controlled by the volume of air flowing through the carburetor, by means of an intermediate unit called a pressure regulator; but there is no direct physical contact between the air and fuel flows. It is this feature that makes this Flow Bench test method possible. With the injection carburetor, it is only necessary to operate a single, "master" carburetor on a test engine, recording once and for all the air flows and the corresponding engine suctions and fuel flows for the entire range of engine operating conditions. From then on the same operating conditions, so far as the carburetor is concerned, can be produced in one or a thousand other carburetors of the same series simply by imposing the corresponding suctions on the air diaphragms of their pressure regulators. It is for this purpose that the Flow Bench is used.

As shown in Figs. 1 and 2, the Stromberg Flow Bench is, when compared with an aircraft engine test stand, a very simple device. It weighs something less than 1100 pounds and can be installed anywhere, requiring only a power supply for the explosion-proof motor that drives its fuel pump and an air supply capable of furnishing a minimum of 25 cubic feet of air per minute at a minimum pressure of 75 pounds per square inch.

When an injection carburetor is tested on this Flow Bench, the suctions used are provided by a Penberthy ejector in the Flow Bench air lines and measured by the water manometer at the extreme left of the backboard. Fuel flows are conducted through a closed circuit from the Flow Bench fuel pump, through a pressure regulator on the back of the board, then through the carburetor, and finally out through the Flow Bench discharge nozzles to the fuel supply tank. This is the lower of the two tanks shown underneath the bench.

These discharge nozzles, as shown in Fig. 1, discharge into an enclosed chamber on the front of the board, just above the drain board or sink in the Flow Bench. This chamber, which has a glass front through which the flow of fuel can be observed, drains directly into the fuel supply tank. The discharge nozzle valves themselves are typical of the discharge nozzle valves used in the carburetor. In fact, the only

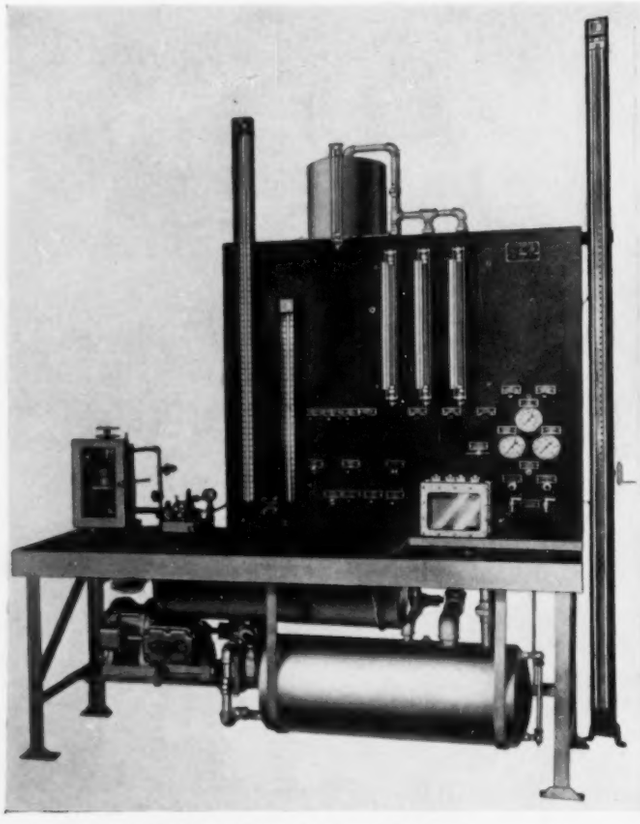

Fig. 1. The Stromberg Injection Carburetor Flow Bench, Front View.

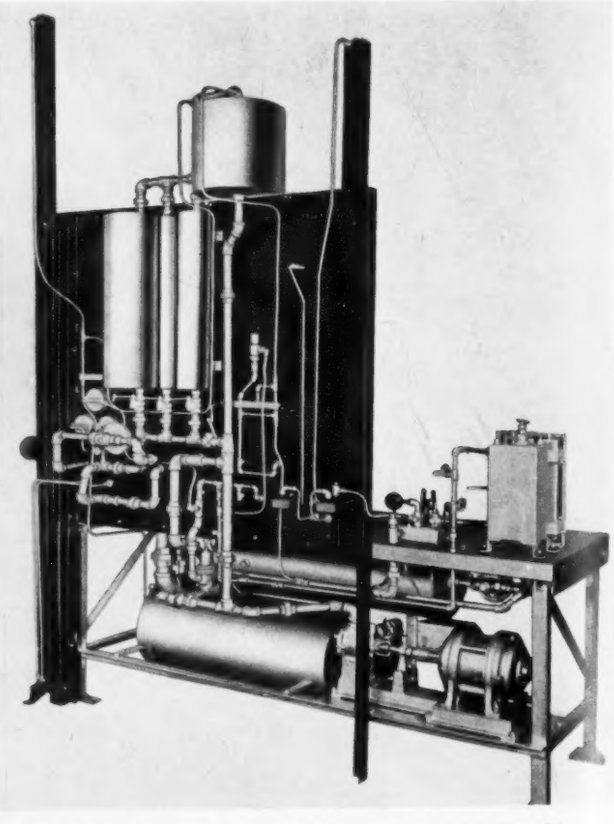

Fig. 2. The Stromberg Injection Carburetor Flow Bench, Rear View.

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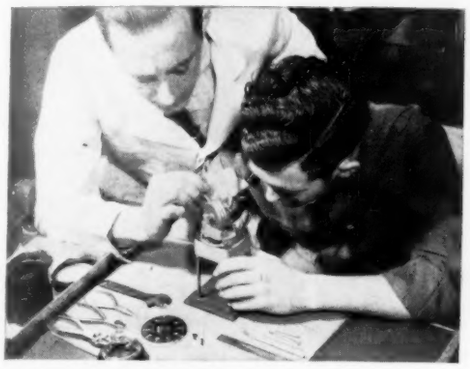

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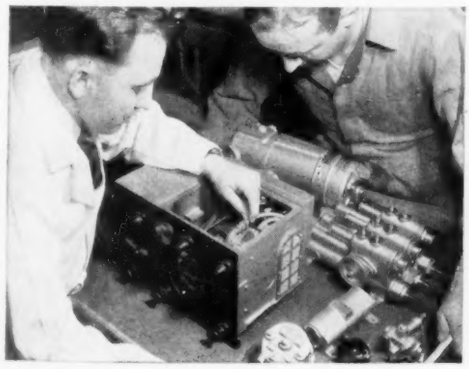

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reason for not using the discharge nozzles belonging to the carburetor itself is that this would require placing the entire carburetor in an enclosed chamber, since the full rated flow of the larger carburetor models runs as high as several gallons per minute.

Metering suctions in the pressure regulator of the carburetor are measured in inches of fuel on the long inverted manometer at the extreme right-hand side of the bench. Fuel flows are measured by timing the flow of specified volumes which are drawn from one or another of the three burettes shown on the back of the board. As shown, these three burettes are supplied in three different sizes, and their sight gages on the front of the board are correspondingly calibrated in cubic centimeters. The large balance tank which extends above the board is supplied with an air line, a vent line, and a sight gage, and is connected with the tops of the three burettes so that the same air pressures can be maintained above the fuel in each of the three burettes as is maintained above the fuel in the balance tank. In this way, almost the same pressure or "head" can be maintained on the fuel whether fuel is being drawn from one or another of the three burettes or directly from the fuel pump.

An air-pressure-actuated vibrator is bolted to the carburetor being tested to simulate engine vibrations while the carburetor is under test. Also, an Ames dial gage is provided for use when necessary in measuring the movement of economizer or enrichment valves, accelerating pump diaphragms, and the like. The three gages at the right-hand side of the board indicate fuel supply pressure as produced by the Flow Bench fuel pump, carburetor pressure (that is, the pressure on the "low" side of the Flow Bench regulator) and discharge nozzle pressure. This completes the equipment for testing the normal, or "ground-level" operation of the Stromberg injection carburetor.

In addition, since these carburetors include an automatic mixture control unit, which compensates automatically for the reduced air densities encountered in high-altitude operation, the Flow Bench also includes an "altitude chamber" for the testing and adjustment of these automatic mixture control units. This "altitude chamber," shown at the extreme left of the Flow Bench, is a sealed box which can be evacuated to an air density corresponding to any specified pressure altitude.

Since the automatic mixture control unit itself is a contoured valve controlled by an aneroid bellows, special fittings are used within this box. The first of these consists simply of a special bracket to which both the bellows and the Ames dial gage can be attached. This permits observation of the expansion of the bellows at various pressure altitudes, which expansion must, of course, be within certain specified limits. The second set of fittings tests the action of the automatic mixture control unit as a valve by providing a measured flow of air into the altitude chamber, past the valve, and out again to the atmosphere. This flow must, of course, be insulated from the vacuum within the chamber so as to avoid changing the pressure altitude at which the bellows itself is being held.

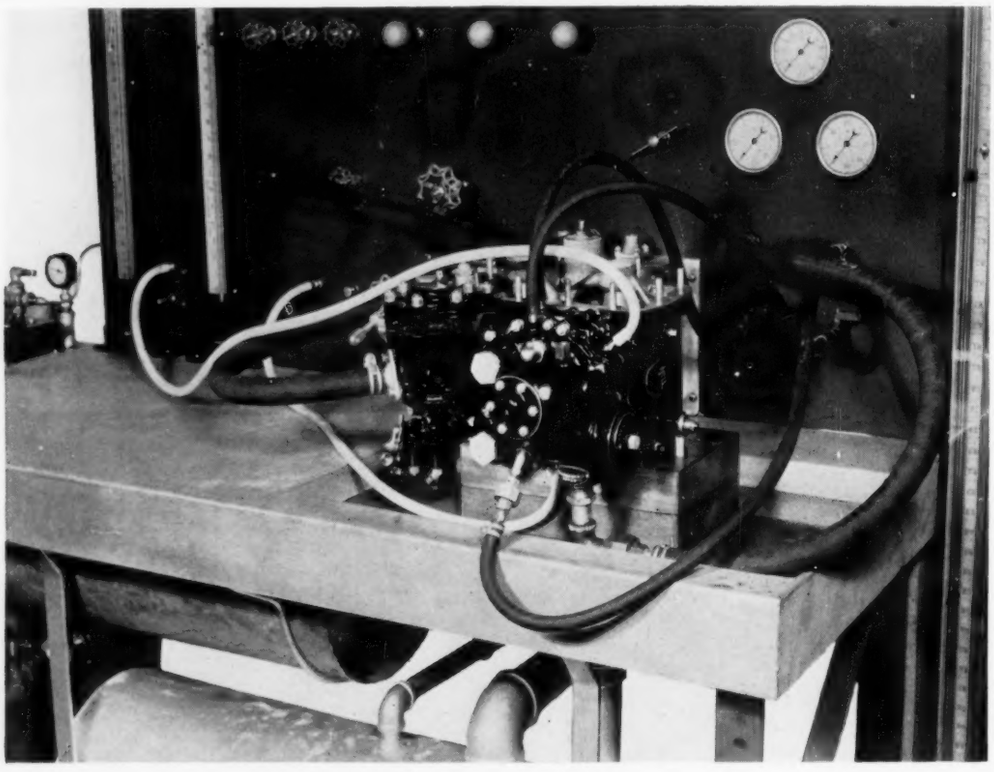
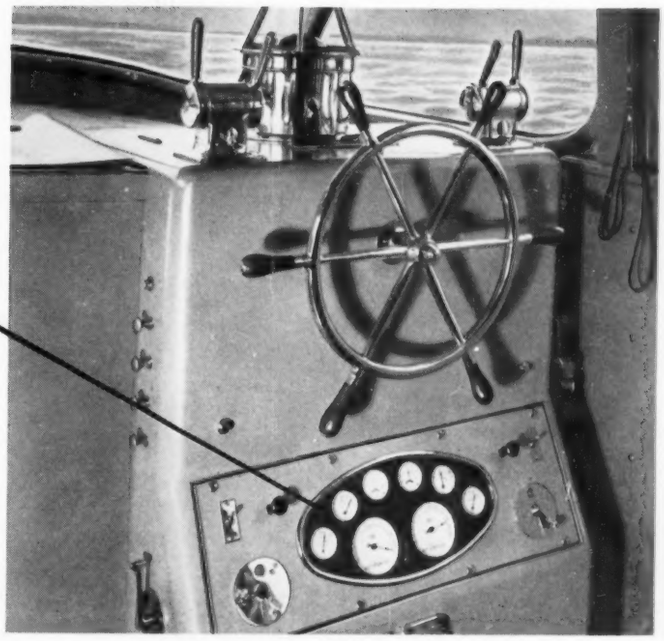


Fig. 3. Testing a Stromberg Injection Carburetor on a Flow Bench.

In this second test, the automatic mixture control unit valve is supposed to offer a specified restriction, as measured by the back pressure on a water column, to a specified flow of air when the bellows itself is exposed to a specified pressure altitude as measured on a mercury manometer. The water manometer used is the same manometer used to measure the Venturi suction imposed on the air diaphragm of the carburetor in the test of the complete carburetor. It is located at the extreme left of the Flow Bench backboard. The mercury manometer used is the one shown just to the right of this water manometer. Since the automatic mixture control unit is adjustable, the operator must be able to reach this unit, loosen its lock nut, and move its adjusting screw until the automatic valve provides the specified restriction. This is done by means of a telescoping wrench which extends in through packings from the top of the "altitude chamber."

The size of the Stromberg Flow Bench set-up is such that it can be installed in a small service shop, in a mobile truck or trailer, or on board ship. Its cost—and weight—are only a fraction of the cost and weight of an aircraft engine test stand or on aircraft carburetor air box. Finally, it permits the testing and calibration of Stromberg injection carburetors in a fraction of the time that would be required by either of these other methods.



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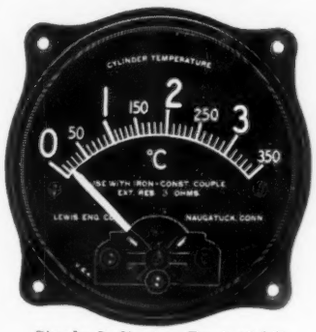
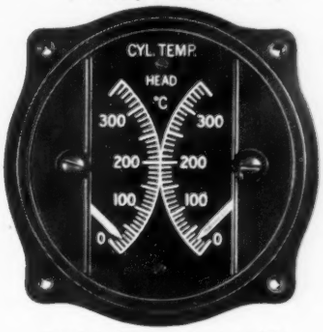
ENGINE CYLINDER TEMPERATURE INDICATORS—THERMOCOUPLE TYPE

(Write for Bulletin 1-2)



Single Indicator Part 17AT



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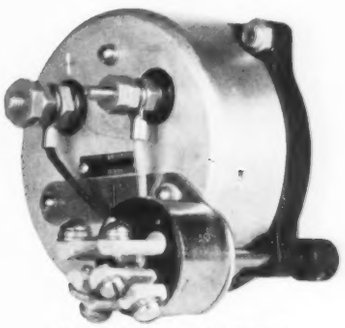

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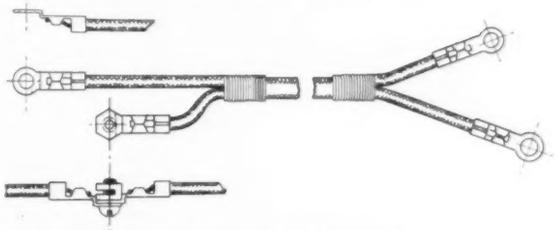

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The Language of Instrumentation

(Continued from Page 305)

out for one purpose helps attain others as well. In 1916, eight years before the word Instrumentation began to be used in industry, the Fluid Meter Research Committee of the A.S.M.E. undertook to classify all fluid meters and in 1922 they put forth a classification into two Divisions, namely Positive and Inferential. The first Division was itself divided into two Classes and the second Division into six Classes; then each Class was divided into Types (28 types altogether). Note that the prime list—the list of two Divisions—is exhaustive. This rational A.S.M.E. scheme won the admiration of an engineer to such an extent that he worked out similar ones (starting with "positive" and "inferential") for other kinds of instruments. Here is the mutual-benefit part of the story: in the course of the detailed work of classifying speed-measuring instruments, it was discovered that certain types of tachometers represented corresponding types of fluid meters forming a class that did not fit into any of the classes defined by the A.S.M.E. Committee. These classes were mutually exclusive but they were not collectively exhaustive.

CLASSIFY BY METHODS, NOT BY THINGS

A fundamental classification might better be based on the essence—on the "thing-in-itself" of philosophy. Since an instrument is a physical embodiment of a method, a fundamental classification according to classes of *fundamental measurement methods* may be said to be "ideal" in the same sense that the Carnot-Kelvin working substance and the Kirchhoff blackbody are "ideal."

Here are three fundamental classifications of fundamental measurement methods which help to name all measuring instruments:

1. Null	1. Positive	1. Direct
2. Deflection	2. Inferential	2. Indirect

Each pair of terms has been defined by scientific and engineering organizations, for their respective fields. Space limitations prevent a discussion. Suffice it to assert that there are pitfalls: not all matching methods are null methods. The null method consists in balancing one magnitude against another magnitude of like kind and opposite direction, with nothing in between except the null indicator, which only plays the bystander rôle of a referee or umpire.

There are other schemes of classifying *all* instruments on this basis of fundamental measurement methods. Certain approaches do not yield collectively-exhaustive and mutually-exclusive *categories*, but the resulting *terms* have nevertheless proved serviceable in avoiding confusion. For example, modern advances have suggested for optical pyrometry 1. *Visual* and 2. *Autometric*; and for radiation pyrometers 1. *hand* and 2. *autometric*—a scheme applicable to the general field.

There are numerous schemes of classifying *some* instruments on this basis. A few of them have yielded "perfect" classifications. The prime division of fluid meters into "positive and inferential" by the A.S.M.E. has already been touched upon. The A.S.M.E. supplemented it with another: "quantity" meters and "rate" meters, which likewise refers to the primary elements of fluid meters. To electrical instrumenticians we owe the crystallization of the "null and deflection" scheme of classification and terminology, although the distinction between these methods was appreciated long before: in the fields of balances, of dead-weight gages and possibly in others. Among the fields of Instrumentation which have been explored in recent years, with the definite purpose of formulating "perfect" classifications and clear-cut terminologies, are: Temperature, Humidity, Pressure, Liquid Level, Time (control only), Speed (measurement only), Automatic Chemical Analysis, etc. In some instances, the application of Methodology yielded results which were astonishing and perhaps "revolutionary." One —that of Temperature—may be reported, if only because of its "surprise ending":—

Since a method of measuring temperature is a method of utilizing an effect of temperature, a classification according to fundamental categories of *utilized effects* suggested itself on the occasion of the American Institute of Physics' Temperature Symposium. For its prime division into a con-

ven[illegible] small number of collectively exhaustive and mutual[illegible]xclusive categories, it began with a consideration of t[illegible]fact that the whole practice of temperature measurem[illegible] is founded on fixed points. It always is because of a *di[illegible]ntinuous* effect of heating or cooling a substance when [illegible] undergoes a change of state that this substance has tem[illegible]atures of equilibrium. Such effects are always *reversible*; and the combination makes possible the use of these fixed points. Therefore the basic methods defining the international standard are those which utilize *discontinuous reversible* effects. The great majority of methods used in practice, of course, are based on *continuous reversible* effects. A pyrometric cone is an example of a *discontinuous irreversible* effect. These considerations led to the following prime division into five mutually-exclusive and collectively-exhaustive categories:—

1. Methods utilizing discontinuous reversible effects.
2. Methods employing continuous effects.
3. Methods utilizing irreversible effects.
4. Combination methods.
5. Miscellaneous methods.

The fifth category was put in for the sake of prudence (or, rather, conservatism) and no imaginable method of measuring temperature was ever put into it in the course of the ensuing discussions. The fourth category, as explained in the original disclosure, is not superfluous. The classification seems to be a "perfect" one, BUT—here is the surprise ending—there are no terms available for adoption, so that new ones would have to be coined. Almost comical, indeed, is the need of new terms to denote the two mutually-exclusive and collectively-exhaustive Classes that make up Division 2 ("effects of properties of bodies" and "effects between bodies") and especially three of the four mu-ex. and col-ex. Types of effects between bodies. The second of these four Types is described as "effects at interfaces" and it is in turn divided into three Sub-types—none termed a thermoelectric pyrometer! (A method is not a thing!)

INSOLUBLE PROBLEMS?

There are provinces of Instrumentation Terminology where classifications into mu-ex. categories are probably impossible—particularly those word-fields pertaining to *continuities* where there exists an infinite number of grades from one extreme to the other, like from "absolutely good" to "absolutely bad."

Sometimes it seems as impossible to define the limits of the continuity as it is to establish arbitrary dividing lines and name the "grades" thus fenced off from one another as is done with price ranges, etc., on a numerical basis.

One of these infinite gradations is the *behavior* of automatic controllers—sometimes of one automatic controller—*on duty*. True, we can *distinguish* certain definite classes of modes of control and then name these classes without anyone confusing "marble" with "dolly." But in most cases we merely adopt terms pertaining to things—not to behaviors on duty.

Take the simplest term: "on-and-off." If the cyclic action of an "on-and-off" controller is extremely rapid in regard to its application, then its mode of control is "throttling." Example, a "vibrating" voltage-regulator giving "stepless smooth control."

The same difficulty—nay, impossibility—confronts us in defining the "degrees" of the "positiveness" of certain instruments employing measurement methods termed "positive." [Interested readers, please turn to pages 325 and 326.]

We are stumped also in the word-field pertaining to temperature measurement methods employing "effects at a distance." Custom says there are two fundamental methods: "radiation pyrometry" and "optical pyrometry." These terms are not only arbitrary but indefinite. We can't define the dividing line because (among other reasons) there are no "total" radiation pyrometers or "monochromatic" optical pyrometers. [Interested readers, look up *Instruments*, Nov. 1940, pages 340-358; Dec. 1940, pages 383-390.]

Same with "self-regulation" of controlled thermal processes: where does it begin and end; and how can we name its infinitely-varied "kinds" and "degrees" when the system under study is not the process but "the-controller-and-its-application"?

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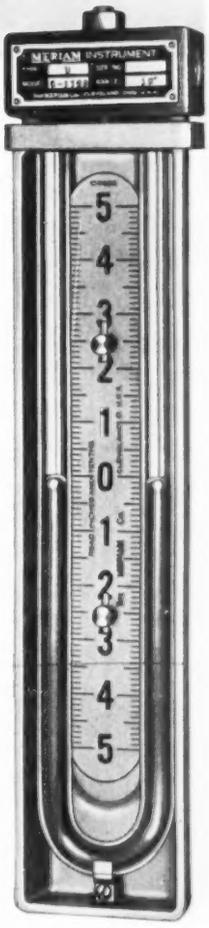

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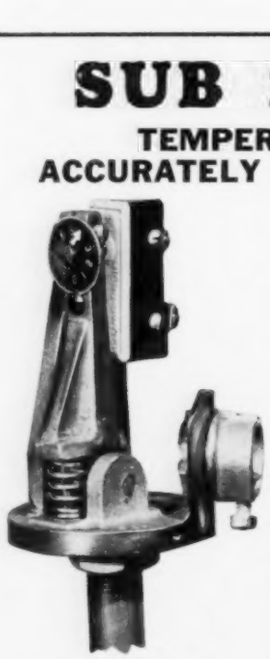

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APPENDIX

SOME "KINDS" OF INSTRUMENTS

(Kinds denoted by participial adjectives. Alphabetical arrangement. Word *instrument* left out after each heading. First prepared in 1927-28 for Dr. Allen Rogers' *Manual of Industrial Chemistry.*)

Balancing. A measuring—but not necessarily an indicating—instrument employing the null method of measurement wherein one effect of the magnitude to be measured is manually or automatically balanced by a calibrated and adjustable effect of like kind and opposite direction. An indicating element is employed to show a state of balance and also —in some cases—to measure the excess of either effect over the other. Examples: equal-beam scales; null-method pressure gages, tachometers, potentiometers, etc.

Checking. 1. A specialized form of testing instrument, i. e., for occasional or intermittent use, not for continuous use. 2. An instrument in continual use for managerial "checking" as of employees' in and out time, etc.

Controlling. An instrument which automatically controls, corrects, governs or regulates (1) the processing, working or storage condition or (2) the physical or chemical property of matter or (3) the proportioning, to which it is applied. Generally used continuously and permanently installed.

Mention must be made of the somewhat confusing use of the term "controller" to designate an operative mechanism, which depends on a control instrument and without it is entirely useless for automatic control purposes. This usage comes from electrical engineering, a field in which various hand-operated devices are called controllers, and it is here to stay. It is so firmly entrenched that the same engineer who speaks of a temperature controller operating a diaphragm-motor will also speak of a pyrometer operating a temperature controller—the "pyrometer" being a pyrometric controller and the "controller" being a motorized valve. In the field of Instrumentation the term "automatic controller," or "controller" for short, is applied preferably to an *instrument* which, once set, will—in conjunction with its auxiliaries—make automatic control possible. [This paragraph transposed here from page 24 of *Fundamentals of Instrumentation.*]

A *control* need not be an instrument and frequently is used to signify a knob, switch, lever, etc., or an entire non-automatic mechanism such as "aileron control."

Coördinating. See Cycling.

Counting. An instrument or device that counts the number of units such as revolutions, strokes, etc. Examples: a hand counter for shaft revolutions, or an "electric eye" for counting either vehicles passing a point or articles traveling along a conveyor.

Curve-drawing. A form of recording instrument, producing a continuous record of a variable magnitude.

Cycling or Coördinating. The designation cycling *instrument* is seldom used in industrial practice. A cycling controller (also known as a cycle controller, program controller, time-operation controller, etc.) is a mechanism embodying (1) one or more clockworks and (2) means for automatically performing predetermined operations at predetermined times in proper sequence according to either (1) a definite schedule in which all times are fixed or (2) a flexible schedule in which certain times depend on states, stages or conditions. The timed operations may be sudden, as opening or closing valves, or gradual, as in the case of a drying schedule or curing cycle.

Detecting. A signalling instrument or device giving merely a yes or no indication, usually visible (when audible it becomes an "alarm" instrument).

Gaging. 1. Same as *Measuring.* 2. A gage, i.e., an instrument or device which does not assign a numerical value but determines whether the magnitude to which it is applied lies within or above or below a certain tolerance.

Indicating. 1. An instrument that shows what the value of the magnitude to which it is applied *is* at the time that it is read (or what it *was* shortly before, allowing for lag). Examples, a Bourdon gage, a liquid-in-glass thermometer, a boiler gage glass. 2. A detecting instrument giving a yes or no indication without assigning a value, but provided with a visible indicating element. Portable as well as fixed forms are *industrial* so long as the purpose and construction relate to the plant rather than the laboratory.

Integrating. 1. An instrument that automatically performs the mathematical operation of multiplying quantity-

rate by time to give total quantity; or which directly registers the total quantity, as of a fluid in units of volume, or electrical energy in kilowatt-hours, etc. Reserved for instruments applied to variables, not generally applied to counters. (See *Counting*). 2. In photometry, an instrument that performs a *directional* summation of values to give mean spherical candle power, etc.

Measuring. Any instrument capable of assigning a numerical value to any measurable magnitude (condition, property, effect, etc.) Examples: a foot-rule or a wavelength spectrometer, a grocer's scale or a geodetic torsion balance. Not, as a rule, applied to counting instruments and devices.*

Metering. In general a commercial integrating instrument known as a meter. Special types are maximum-demand meters, etc.

Recording. Any instrument, industrial or scientific, which furnishes a graph (usually on a moving chart) of the changing values of the measurable magnitude to which it is applied. It embodies an indicating instrument the indicating element of which (pen-arm, light-beam focused on moving film, printing mechanism, etc.) traces the record which may or may not be a "curve." The record is permanent and therefore shows what the value of the measured magnitude *was* at a previous time. The record may be continuous or intermittent. One recording instrument may be applied to several measurable magnitudes.

Registering. Not a recording instrument, but a form of indicating instrument provided with means of registering maximum or (sometimes *and*) minimum values, such registering element "staying put" until manually displaced. Examples: a maximum-registering thermometer, a cylindrical tire pressure gage. Note, however, that in a meter the mechanism having an arrangement of numerals, etc., which is observed when "reading the meter" is known as the register.

Regulating. See *Controlling*, but note that the term *controller* (which applies also to motor-starting devices, automatic scheduling devices, etc.) is broader than the term *regulator* which, as a rule, applies only to devices for controlling the value of a condition, property, etc.

Sampling. The A. S. T. M. has apparently sanctioned the designation "sampling instruments" for devices which, in spite of their being beautifully made in strict conformity with the Society's specifications, are implements and not instruments.†

Signalling. An indicating, recording or controlling instrument provided with means for visible or audible signalling at predetermined and usually adjustable "points" or values of the magnitude to which the instrument is applied.

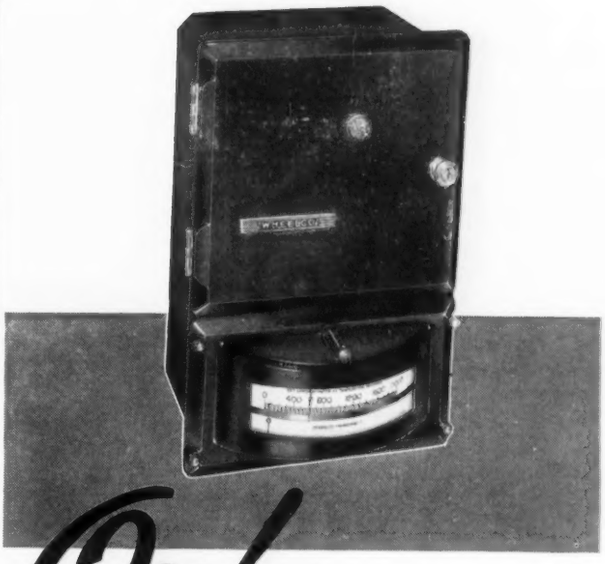
Testing. By definition a non-industrial instrument, not installed on a piece of equipment but kept in the laboratory (or taken out on the job) and used as the occasion arises.

Timing. 1. A time measuring instrument or timepiece. 2. A form of recording instrument, as an operation recorder. 3. An alarm or signalling timepiece which may be set. 4. A controlling instrument which causes an operation to be performed automatically at the end of the period of time for which it is set, such times being ordinarily related to the manual setting operation, but in certain forms to a state, stage or condition independent of the manual setting. Elaborate forms of industrial timing-controlling instruments are preferably called cycling or coördinating controllers.

Totalizing. 1. Any counting instrument or device. 2. Any integrating instrument, particularly one that adds instantaneous values of variables, as a totalizing recording voltmeter.

*Whenever a new measuring instrument is devised and placed on the market an attempt is made (and very properly) to give it a name ending in -meter but *not* hyphenated. It occasionally happens that two or more new instruments appear almost at the same time in response to a new need and that the various sponsors do not agree on a name. Thus we have viscosimeter and viscometer, plasticimeter and plastimeter, etc. But this is preferable to two words of which the second is meter.

†This involves of course, a discussion of the definitions of instrument, apparatus, device, machine etc. The author will not go into it here beyond making the above statement.



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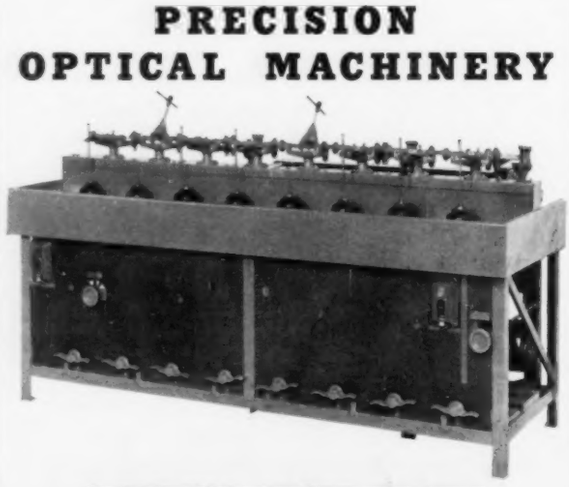

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Metering Bottleneck

(Cont'd from p. 287) In the oil and other meter-using industries, "monkey-wrench and screwdriver mechanics" are either giving way to engineers or studying to be engineers themselves, while the vague classification and loose terminology of former days are giving way to engineering specifications. Not so long ago, the men who specified positive meters did not belong to engineering societies, did not know that a representative committee had laid down a scientific set of unambiguous definitions in 1922; today they not only know it but some of them have discovered that the Report, like certain laws, "has teeth in it" and they sometimes demand the impossible. The greater the proportion of industrial engineers thus "armed" with the Report, the more the situation grows serious. Scrupulous sales engineers, who honestly admit that some of their meters are not truly "positive," suffer under a handicap.

Strictly interpreted, the Committee's definition implies that no matter how low the rate of flow through the meter, every drop of liquid or every cubic inch of gas must actuate the primary device. While some commercially produced weighing meters can meet this requirement, most of the devices in the great field of commercial, industrial and public service volumetric metering, which by usage and custom are called *positive displacement* meters, would be excluded if the letter alone of the definition were adhered to. It obviously is impracticable to manufacture and sell against competition a meter of rotary type or nutating-disk type (for example) which will register at all when, after a period of inoperation, less than a tenth of 1% of its rated capacity is to be metered. The plain fact is that only such types as the valveless wet drum (for gases) and the tilting tank (for liquids) employ truly positive principles whereby, not only when the meter is new but after working parts have begun to wear, every cubic inch is registered and every drop caught. And even a meter in which buckets are filled and emptied is not absolutely positive, because open vessels permit evaporation, so that in the case of a volatile liquid the totalized quantity at low rates of flow is less than that delivered to the meter and more than that delivered from it. Moreover, spouts and valves are not always absolutely positive in their action.

2. General Characteristics of Positive Meters

(a) Readings and Records Obtainable

Most positive meters are quantity meters. Their distinctive characteristic is that they *register* the total flow passed. This registration usually consists of the usual incremental indication readable on a counter, "index," "dial" or "register" but it may be recorded on a chart, a light or short mark being made every ten cycles, for example, and a heavy or long mark every fifty cycles—or a "wave" form of record being produced. When such a chart is clock-driven, the record gives the mean rate of flow between marks or crests, just as the mean load of a domestic meter can be computed from the increment when the time since the last reading is known, but with the advantage over the computing method that variations in rate, during the chart period, show up at a glance.

(b) Suitability for Automatic Flow-rate Control

There has lately arisen a demand for fluid meters with primary devices of positive types and secondary devices giving direct readings of rate of flow. Such meters correspond to the positive direct-reading tachometers—that is to say the integrating chronometric, the conjugating chronometric, and the geometric (these last in principle only). Such meters consist essentially of a positive primary device and of a tachometric secondary.

Why not use an inferential primary device in the first place and get a rate reading directly? Why not use a head meter which is a quantity-rate meter and which, in metering a gas at fluctuating pressures, gives a more correct indication of the B.t.u. supply rate than does an uncorrected volumetric positive meter?

Because there are required—mostly in the chemical industries — dependable indications and/or records of the

instantaneous values of the true *volumetric* rate at all rates of flow, from practically zero to the full capacity of the meter. And the expression "dependable indications" refers not so much to the deflection of a pointer along a scale but to the initiation or "command" of telemetering or automatic-control functions. Only such meters make possible the automatic control of various processes on a positive volumetric basis. Such positive meters serving as elements in automatic-control systems are usually combined with relays whereby auxiliary power operates the rate-control valve. But this is not a logical necessity: a positive meter can serve as a hydraulic motor, as a source of mechanical power for operating the rate-control valve. To operate the valve under command of a controller, this power need only be stored in the form of energy. The simplest energy-storage form is a spring. This principle is employed in a self-operating automatic flow controller with positive-displacement primary element brought out by Builders Iron Foundry.

Positive meters with register drive shafts protruding outside of the body are also especially suitable in many cases for "ratio control" or maintaining the proportionality of a continuous mixing of two fluids at all rates of flow: all that is necessary is to set up a pair of them with their shafts geared to each other. A variable-speed connection, instead of constant-ratio gearing, permits adjusting the proportionality.

[Extract from Dec. 1932 instalment]

Logical consequences of the availability of more accurate meters for various particular fluids are (1) the revision of standard specifications and (2) the appearance of specifications where there were not any.

Natural consequences of the widespread adoption of rigid specifications for the metering of any fluid are (1) standardization of the meters made by different manufacturers —especially when dimensions and types are specified irrevocably—and (2) discouragement of "revolutionary" improvements. This is especially true when specifications permit 10% error at a stated "minimum test flow" which is more than 1% of rated capacity, and greater errors at smaller flows. Excellent work is nevertheless being done by bodies that have laid down standard specifications for domestic meters. In this connection it is well to mention (1) that some manufacturers of nutating-disk cold water meters make various "grades"—some registering 95% or more of the actual flow, instead of the specified 90%, when tested at "minimum test flow," and otherwise being suitable for industrial service; (2) that two or three makers of diaphragm gas meters, in like manner, can supply industrial users not only with special high-pressure meters but also with high-grade domestic models that prove satisfactory for many engineering applications.

The growth of the petroleum, automotive, aviation and oil-burner industries has fostered prolific development of specialized liquid volumeters. This process is still going on. New specifications require volumeters capable (without frequent cleaning) of measuring sand-laden crude oils, and gasoline meter specifications being proposed are so rigorous that some types of meters, with or without adjustable by-passes, would be excluded.

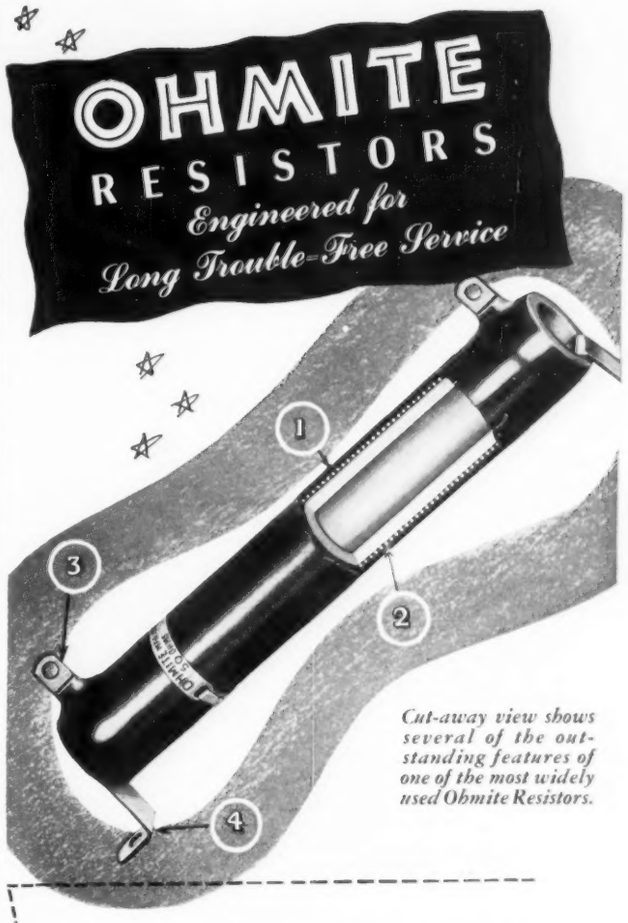
This large-scale metering of costly liquids and this rapid development of liquid volumeters are focusing attention on the characteristics of various new sub-types. For example, the various gasoline volumeters lumped under the head of "Piston" comprise several distinct sub-types.

There also have been developments in meters other than the piston meters.

Table XXIII-1 represents the order in which the various types of positive meters are discussed below. The author does not presume to offer it as an "improvement" on the A.S.M.E.'s brief official classification, but only as a more nearly comprehensive and rational presentation.

(c) "Positiveness"

More than 95% of liquid volumeters in industrial service belong to piston and disk types. One group of engineers maintains that the distinction between "disk" and "piston"



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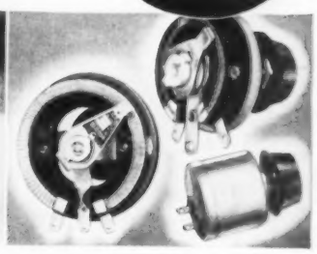

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SINCE 1901 COMBUSTION INSTRUMENTS AND CONTROL MICHIGAN CITY, INDIANA, U.S.A.

should be ended; the other people claim that the disk type should be excluded from the elite "positive" class.

Which is right?

To some extent, both; from a realistic standpoint, neither. This is the conclusion reached by taking a good look at the liquid displacement meters that are being produced and considering also those that could be made.

If one scrutinizes the manufacturers' own blueprints for possibilities of leakage and slippage in the various designs of meters, he will discern that there is no sharp line dividing meters that are of positive design from meters that depend entirely on small clearances between rigid moving elements and rigid walls, that is to say on the closeness of manufacturing tolerances. It will be seen that in design and construction, in theory and practice, *there are degrees of "positiveness."* It would indeed be possible to establish a continuous scale of infinitesimal gradations, from an ideally positive meter to a "displacement" meter with such large clearances that its registration curve has no "flat" portion. ("Flat" could be defined.)

The basis for such a scale of the *figure of merit*, with regard to positiveness alone, would of course be the registration curve—not necessarily the intrinsic accuracy of the meter being graded. At one extreme would stand a design which has never been commercially produced, namely a piston meter which would measure any fluid, even hydrogen, without leakage or slippage. The other extreme would characterize an equally inexistent kind of meter: one having a plunger or a piston or a disk (but not a velocity-impelled rotary element) with intolerably excessive clearances—a meter, in fine, belonging neither in the "Volumetric" class nor in the "Current" class—a meter, therefore, which is neither positive nor inferential.

All this may sound far-fetched, but a line of reasoning *ad absurdum* was needed to demonstrate: (1) that since the various liquid meters in question do not arrange themselves into mutually-exclusive categories, *any* scheme of classification must be a compromise; (2) that to discard the A.S.M.E.'s compromise *classification* for a purely scientific *gradation* would be impracticable.

The outstanding fact is that no displacement meter is ideally positive. But as long as volumeters are generally considered positive, the non-piston types seem to be as much entitled to this qualification as are the piston types. What is of interest to users in the processing industries is to know that *some forms of the piston type depend more on clearances between fixed walls and displaced members than do some forms of the other types.*

Finally, positiveness is not the only basis of evaluation: pressure-loss characteristics, possibility of adjusting the register speed, initial and running costs, effects of changes in the physical properties of the metered fluid, the cleanliness of the metered fluid, the presence of abrasive particles, and other considerations, should not be lost sight of in the flurry over pistons and other forms of reciprocating or rotating or nutating elements.

New York Instrument Society

A New York Instrument Society organization meeting will be held at the Hotel Roosevelt, September 29th at 8 p.m. All interested individuals are invited to attend. For additional information 'phone or write, George Kauer, Jr., 4155 Case St., Elmhurst, L. I., N. Y.

Locating Laboratory Instruments

Research workers seeking instruments required in their work but difficult to find are invited to communicate with D. H. Killeffer, chairman of the newly appointed Committee on the Location of New and Rare Instruments of the National Research Council. The plan of the committee's activity is to assist in locating needed instruments of types not ordinarily available through accustomed channels.

Assistance is particularly desired from owners and builders of instruments falling within the new or rare categories which might be made available to others through sale or for temporary use under mutually satisfactory conditions.

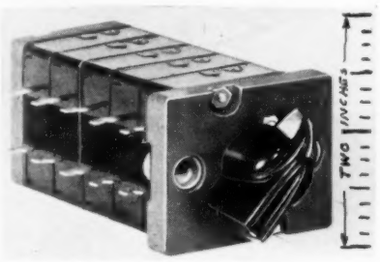
Communications should be addressed to: D. H. Killeffer, 60 East 42nd St., New York City.

The Month's NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

Multicircuit Switch for Aircraft Service

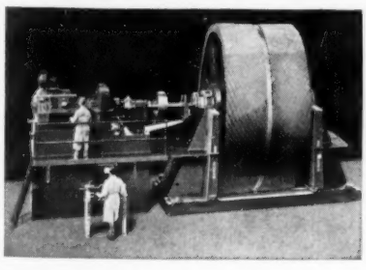
New multiple-circuit switch for aircraft service opens, closes, or transfers as many as twenty circuits simultaneously by means of a two-position operating knob. Contact



mechanisms used are maker's "switchettes" stacked in pairs. Each "switchette" is snap action, double-break construction, said to give a high current rating. New switch is available with from 8 to 20 "switchettes," and in either single-circuit or two-circuit form. A shaft toggle switch insures positive switch position. New Multicircuit Switch meets specifications set up by the U. S. Army Air Forces for devices of this type. Weight varies from 5⅓ ounces to 10⅔ ounces, depending upon size.—*General Electric Co., Schenectady, N. Y.*

Balancing-machine Line Has 1-oz. to 50-ton Range

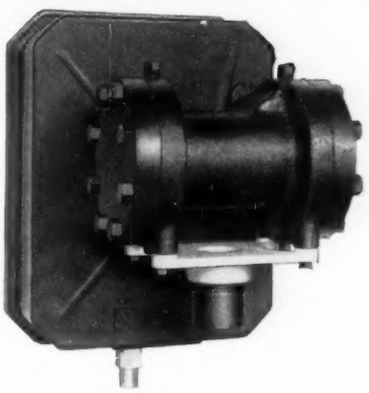
Announcement states that "Gisholt Machine Company development engineers have broadened the over-all range of the Dynetric Balancing Machine line to extremes of



1 ounce and 50 tons." This expansion of effective static and dynamic balancing capacity is said to have been brought about by two major developments: (1) new "Floor Type Dynetric Balancing Machine," built to balance parts up to 100,000 lbs. in weight, 240" in length, with 200" swing, has successfully passed all tests and is now in use; (2) "Type S Dynetric," first to be manufactured and smallest of entire line, has been perfected to balance parts weighing as little as one ounce. Illustration shows: (1—at rear) Floor Type Dynetric Balancer as used to balance 50-ton marine reduction gear 16'8" diam.; (2—left front) "Type S Dynetric Balancer."—*Gisholt Machine Co., 1331 East Washington Ave., Madison, Wis.*

Aneroid Manometer for Flow or Liquid Level Instruments

For pressure or differential-pressure measurement—as the responsive element in flow-rate or liquid-level controllers, recorders or indicators, there is announced a new aneroid



manometer. Absence of mercury or other liquid possibility of product contamination and hazard of mercury being blown due to line surges or carelessness. Further advantages are that sealing liquids are rarely required and vital mercury is released for the War Effort. Replacing the stuffing box is a new torque tube assembly which gives a completely closed system and is designed to eliminate friction and lubrication. New assembly does away also with lost time involved in maintenance. Friction, lost motion and wear are further reduced by absence of internal pivots and springs. Metal bellows respond to pressure variations and insure fast response under ordinary circumstances with immediate reaction to sudden changes in flow. Bellows are built to withstand high over-range without damage. Under steady flow conditions, new Aneroid Manometer is accurate within 1% of scale range. It is available for all types of indicating and recording flowmeters and controllers and is supplied for standard ranges between 20 and 500 inches of water. The range can be changed on the job by substituting precalibrated torque tubes.—*Taylor Instrument Companies, Rochester, N. Y.*

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Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

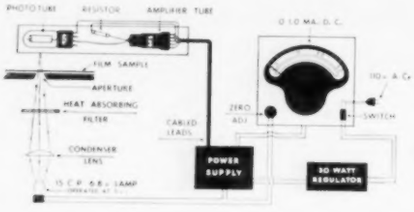
BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

Photoelectric Densitometer

New "Ansco Sweet Densitometer" (named for Monroe H. Sweet of the Agfa Ansco Research Laboratories who developed it) is said to present many striking advantages

over previous methods of photographic density measurement used in laboratories and testing departments. It is said that readings can be made rapidly by even inexperienced operators with a high degree of accuracy and with a minimum of visual



fatigue. Basis of instrument is in the use of a photosensitive tube which, when placed in the path of a beam of light, varies the flow of an electric current in proportion to the intensity of the light. This current, after amplification, actuates an indicator calibrated directly in terms of density. Electronic circuit is stable over long periods of time and has a response such as to permit uniform calibration of the indicator scale directly in terms of density. Mr. Sweet's unique circuit is said to give the new densitometer these characteristics, in addition to ease and accuracy of operation. The sale of the instrument is subject to priority regulations.—*Agfa Ansco, Binghamton, N. Y.*

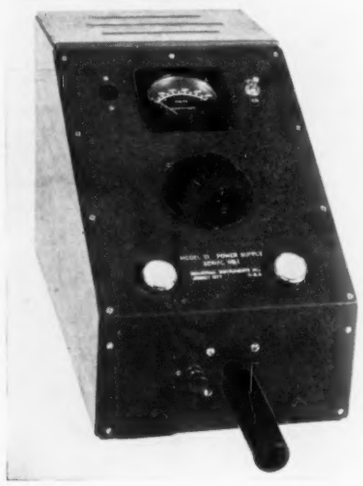
Combination Dual Tachometer and Synchroscope

New Combination Dual Tachometer and Synchroscope for twin-engined aircraft is said to represent a new step in instrument panel simplification. It is a three-in-one arrangement which combines, in the space of one standard size instrument dial, three instruments normally observed together. Synchronization can be quickly obtained by matching tachometer pointers with slight adjustments from the synchroscope. As seen in illustration, new instrument has a standard size dial with two concentric pointers—one for each engine—and synchronization is indicated by the rotating

subdial viewed through the window. Dual Tachometers, without Synchroscope, are also available. The new indicators operate in the same manner as maker's standard (remote indicating) electric tachometer and synchroscope units. Maker's standard electric tachometer generators are used and, if desired, the new units can be used in combination with standard units. For ease of servicing, the mechanism for either of the two motors or the synchroscope can be removed from the instrument case without disturbing the other units. New Dual Tachometers will be made available with either the standard 3500-r.p.m. or 4500-r.p.m. range. Although the new instrument is not in production as we go to press, information is being released so that it can be included in the design of new planes.—*Kollsman Instrument Div., Square D Co., Elmhurst, L. I., N. Y.*

Voltage Breakdown Tester

New Voltage Breakdown Tester provides simple, positive, safe and quick means of testing voltage breakdown of materials or components. It consists essentially of a step-up transformer accurately controlled by a Variac; current-limiting resistors safeguarding the equipment in event of a dead



short; a relay indicating by means of a panel light when there is a breakdown; a direct-reading voltmeter; and the rectifier and filter circuit providing the high-voltage d.c. The high voltage is applied by means of a suitable fixture, or by a test prod connecting with proper receptacle on the instrument panel, as well as by a second connection to the ground binding post on the panel. The instrument connects with the usual 110-volt 60-cycle a.c. A ground clip goes on nearest grounded conduit or water pipe. A power switch turns the instrument on and off. To set the instrument for test the Variac is rotated counter-clockwise until desired voltage is indicated. When material or component is tested, a warning light on the panel flashes on to indicate breakdown. A second light indicates that the instrument is "alive." Two models are offered: "Type P-1," 0-400 v. d.c., and "Type P-3," 0-10,000 v. d.c., both continuously variable over entire range.—*Industrial Instruments, Inc., 156 Culver Ave., Jersey City, N. J.*

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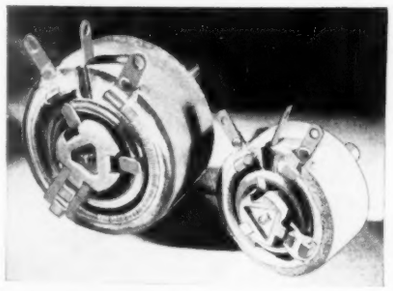
Portable A-c. and D-c. Instruments

New "P-14" portable a-c. and d-c. instruments are announced for general field service use where an inexpensive unit is required. They are said to be characterized by modern design, accuracy, sturdiness and reliability. Molded cases are fully insulated and magnetically shielded from stray field

influence. Scale length is 3.2" a-c. and 2.8" d-c. Instruments are available with or without covers, have an accuracy of ±1% of full scale, are equipped with mirrored dials and knife-edge pointers which aid in making close readings. "P-14" instruments are available in a variety of single and multiple ranges providing for the measurement of a-c. volts, amperes and milliamperes; d-c. volts, amperes, milliamperes, and microamperes. Ranges and combinations of ranges are said to have been carefully chosen to meet every need of test men, laboratory technicians and research engineers. Combinations such as four-current and three-voltage ranges are said to make this the most complete and flexible instrument available in this classification.—*Westinghouse Elec. & Mfg. Co., 7-N 20, East Pittsburgh, Pa.*

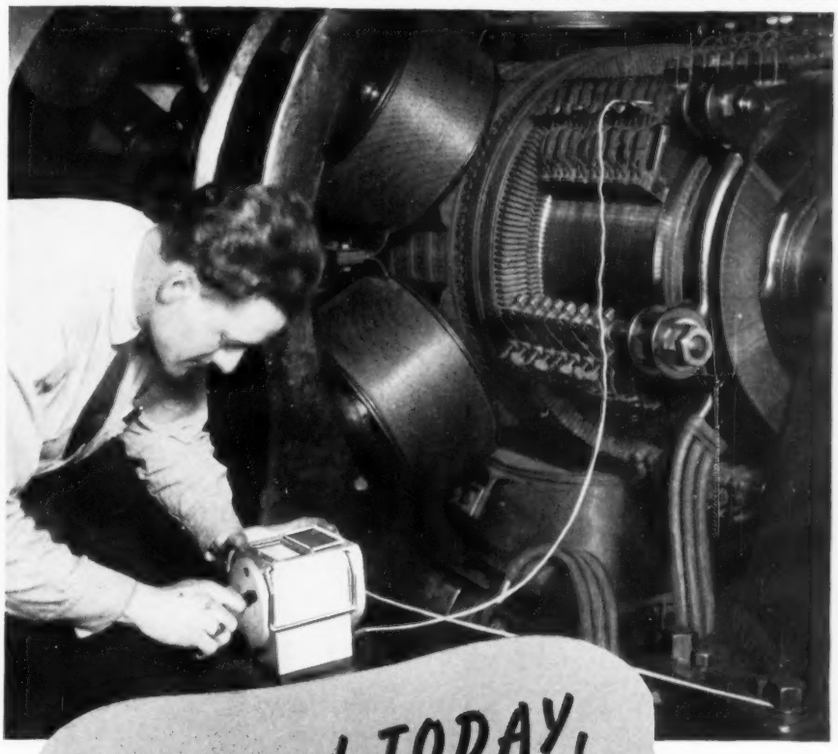
Extra-heavy-duty 50-watt Power Rheostat

New 50-watt rheostat is similar to the previously introduced 25-watt unit (full description Nov. 1940 *Instruments*, page 330) except for its larger size. Resistance wire



wound on insulated metal core which distributes heat at intermediate rotational settings. Resistance element imbedded in ceramic housing with an inorganic cement, resulting in a solid thermal mass. Graphited-copper contact shoe. Contact pressure is provided by a helical spring, concentrically mounted about shaft whose action is evenly distributed by use of a tripod-type contact carrier. Contact insulated from metal shaft by a center ceramic insulator, thus providing a "dead" shaft and mounting bushing. Units available in any resistance value up to and including 10,000 ohms. —*Clarostat Mfg. Co., Inc., 285-7 N. 6th St., Brooklyn, N. Y.*

TAKE TIME TO TEST . . . and SAVE TIME



. . . and TODAY, TIME is priceless

Although "Megger" Insulation Testers have been used for years by industry to detect and forestall electrical breakdowns, their use today has assumed an importance out of all proportion to the cost of the instrument—or the amount of time spent in using it. It is not merely a matter of dollars and cents. Production time is priceless . . . and electrical equipment is most difficult to replace. *Minutes* with a "Megger" Tester can save *Days* of delay.

Under the stress of present demands, everyone who is directly or indirectly responsible for keeping motors, generators, wiring and other electrical equipment in good operating condition, should be fully acquainted with the advantages to be gained by the use of a "Megger" Tester. Write us for a free copy of the Pocket Manual of "Megger" Practice No. 1420-I.

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Combined Instrument and Data for Weather Forecasting

New "Kenyon Weathercaster" is a combination of a four-dial instrument similar to a circular slide-rule, and a book of data. Illustration (approx. one-third actual size) shows the "front cover" on which the dials are mounted. Not visible—because transparent—is the "outer front cover" which is

a strong sheet of clear plastic. The cardboard "pages" of the device contain complete and easily-followed instructions for use, as well as "comprehensive and detailed data on meteorology which combine to make this instrument really an epitome on the subject of meteorology." The forecast obtained by a user is said to cover a period of 12 to 24 hours and applies to a region with a radius of 30 to 50 miles from the point of observation. Manufacturers do not claim that this new device alone provides forecasts: the user must read his barometer, observe wind direction, etc. What the device does is to apply the well-founded mathematics of meteorology in such manner that the user is spared the tedious calculations of professional meteorologists.—*Kenyon Instrument Co., Inc., 1345 New York Ave., Huntington, L. I., N. Y.*

Limit Bridge for Production-line Resistance Tests

New "Electronic Limit Bridge Model No. 670," is said to make possible rapid resistance measurements within narrow tolerances. A direct reading is given of the percent deviation, plus or minus, of resistance values compared to any predetermined standard. Dial is calibrated from zero center to 10% deviation on either side. With each main division on the dial indicating

0.5%, it is said that fractional divisions showing deviations of one-tenth of one per cent can be read quickly and easily, and approvals or rejections promptly determined. Comparison is made against a predetermined internal standard of any arbitrary value selected. While this is supplied as part of the bridge, provision is also made for using any other value of resistance desired by switching to "External Standard" and connecting the new standard value to the corresponding terminals. Component resistors are said to be accurate to 0.1% and the indicating instrument is a 4½" galvanometer having a sensitivity of 25-0-25 microamperes. Engraved Bakelite panel is heavily shielded. Two Type 1C5GT tubes are used in the circuit. "Model No. 670" is battery-operated and completely self-contained in a natural-finish solid oak carrying case.—*Radio City Products Co., Inc., 127 W. 26th St., New York City.*

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Portable and Stationary

Indicating Speed and Total Run.

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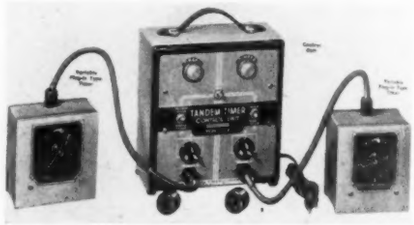
Oldest Thermometer Manufacturer in Philadelphia

Continuous-repeat or Single-cycle Timer

New "Tandem Timer" is said to possess unusually versatile features of particular value in production departments, laboratories, and for life testing of electrical apparatus. It permits "practically any timing sequence that may be desired," being essentially a control unit with two variable plug-in type timing elements. With timing ele-



ments adjusted to their correct respective time intervals, each cycle of operation will follow the other continuously in regular sequence. When the timer dials are once set at the time interval desired, further adjustments are unnecessary until a new sequence is required. Automatic reset features make a continuous, as well as a single, cycle of operation possible. Plugging in of different timing elements is accomplished in a matter of seconds. For example, using a setup for a double solenoid where one solenoid is to actuate for 4 seconds and the other solenoid for 2½ seconds in sequence on a life test, the following units are used: a "CU-2" control unit connected to two "TE-14S" elements; one solenoid connected to the load contacts on Timer No. 1 and the other solenoid to the load contacts on Timer No. 2. With these connections, the first solenoid would be actuated 4 seconds and released when Timer No. 2 started on the 2½ second period. This cycle will keep repeating until shut off. "Tandem Timer" can be set for single operation, however, by merely placing the single cycle push-button with the toggle switch at single cycle position. Control cabinet (8½" × 8½" × 5") contains on-and-off toggle switch, repeat and single cycle toggle switch, single cycle start push-button switch, pilot lamps, receptacles, and sockets into which are plugged the two timing elements which command the s-p.d-t. load relays. Contact circuits of load relays may be powered with the particular voltage and current necessary for test or production requirement. Load relay contacts are rated at 110 volts, 10 amps., a.c. Timing elements are synchronous motor driven, automatic resetting timers, contained in a 5" × 5" × 3" steel box. Six standard models are available, offering setting of ¼ second to 2 hours, 45 minutes. Longer time cycles are built to specification.—*Industrial Timer Corp., 113 Edison Place, Newark, N. J.*

Light Meter for Luminous Paints

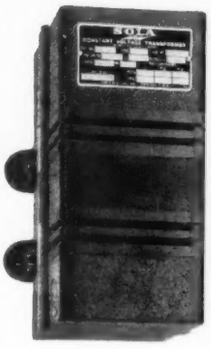
An "Electronic Photometer" is available for testing the micro-lambert output of luminous paints and for determining their decay curves. It operates with phototube and d-c amplifier. The phototube is mounted in a "search unit" connected by cable to the instrument proper. The photometer is self-contained and built into a portable housing. Some models are completely line operated, others are operated by dry-cell batteries. New light meter's applications are said to comprise many fields other than luminous paints: high sensitivity of instrument makes it suitable for all measurements of low light values, replacing barrier-layer photocells and delicate galvanometers. New photometer is available with phototubes having their main response in the red and infrared or with phototubes of high sensitivity in the blue and ultraviolet. As a result, instrument will measure infrared reflection of surfaces, fluorescence of paints and solutions, and ultraviolet absorption of transparent materials and liquids. Instrument finds further applications in measurement of narrow light beams as required, for instance, in determining specular gloss, in evaluation of density of spectrographic lines, in gaging of small openings or narrow slots, etc.—*Photovolt Corp., 95 Madison Ave., New York City.*

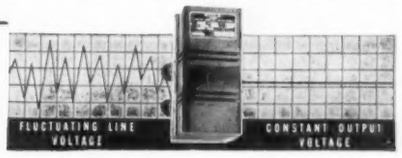
Explosion-proof Timers

New line of Explosion-proof Timers meets specifications for operations in atmospheres containing gasoline, naphtha, petroleum, benzol, acetone, lacquer solvent, natural gas, etc. Illustration shows "Type TD1C Explosion-proof Time Delay Relay" which is laid out for panel-board mounting with the setting knob and dial projecting. Within this housing it is feasible to mount either a TD1C or TD1 with a small relay. The latter construction would be used where it is desired to control the timer from remote located momentary start button. The time

delay relay illustrated is used for a-c. circuits to supply an adjustable or a fixed time delay between the closing of one circuit and the subsequent closing or opening of a second circuit. Typical uses are controlling time of heat treating; controlling sequences of operations by the use of timers connected in multiple; mixing operations, baking, control of chemical processes, etc. Timers are supplied with either a manual reset or an automatic reset. Micrometer setting, for adjustment of the time cycle, consists of a worm gear and knurled knob; is said to make it possible to set the timer to within new limits of precision. Motor will start and stay in synchronism on ±10% of rated voltage; is provided with an adequate supply of sealed-in lubricant and therefore requires no special attention. The switch used is totally-enclosed light-acting quick-break type with silver contacts rated to carry a 1/3 h.p. motor load, 250 watt incandescent lamp load, 1200 watt heater load or solenoids in which the in-rush current does not exceed 15 amperes at 110 volts. Available with normally-open, normally-closed or double-throw contacts.—*R. W. Cramer Co., Inc., Centerbrook, Conn.*

CONSTANT VOLTAGE
is the answer to the precision demands of
SCIENCE and INDUSTRY for DEFENSE





Every electrically operated INSTRUMENT employed in the production of materials of war needs CONSTANT VOLTAGE protection against line surges and fluctuating voltage levels caused by overloaded power lines. Sola CONSTANT VOLTAGE TRANSFORMERS will deliver a perfectly stabilized output voltage, even though line voltages vary as much as 30%. No moving parts. Instantaneous in action. Self-protecting against overload or short circuit.

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Write for new Engineering Bulletin on the VIBROTEST . . . the insulation testing instrument having an amazing combination of advantages: (1) self-contained power source produces constant potential of 500 volts; (2) compact, readily portable; (3) easily read scale showing Ohms and Meghoms—also, A.C. and D.C. volts; (4) ingenious circuit design with standardization of synchronous vibrator; (5) can be operated with one hand, level or at an angle. New Bulletin—generously illustrated—gives specifications, uses, prices. Write for it today.

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VIBROTEST

TRU-VAC
VACUUM GAUGES
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Shown at left is meter box of our model No. 6 gauge.

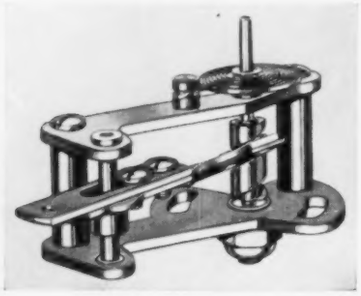
This gauge successfully used by many of America's foremost manufacturers.

Send for circular on our new low priced D.C. operated gauge.

CONTINENTAL ELECTRIC CO.
GENEVA, ILLINOIS

Pressure Gages with New Mechanism

Pressure indicating gages are announced, embodying a new and improved type of gearing in the form of a cam and roller movement, employing a sector-shaped driving cam and a driven helical roller. One end of the pivoted cam is linked to the tip of the Bourdon tube, while the other end is aligned with and fits freely into the thread of the roller. A hair-spring limits the contact between cam and roller to only one side of each element, and prevents backlash. New cam and roller movement is said to provide smooth and constant transmission of motion from Bourdon tube to pointer. As edge of the cam is in constant contact with wall of helical thread, there is no lag nor lost motion between these parts. Overstretch or collapse of Bourdon tube cannot jam the internal mechanism, it is said. The driving cam has a facing of plastic material and tests have shown that there is no wear on contact surfaces of cam or roller after millions of cycles of operations. The ball-shaped roller pivot, riding on a bearing of dissimilar metal, is said to assure frictionless rotation of the roller. Unique with the new "Certified Gauges" is a recalibrating mechanism by means of which it is possible to reset the pointer to zero to correct for drift or set of the Bourdon tube. A back adjustment screw, available on all large gages, effects positive recalibration without the necessity of opening the case: adjustment can be made while the gage is operating under pressure. Such recalibration disturbs neither the cam and roller movement nor the Bourdon tube—the angularity of the linkage remains unchanged. A turn of the "Adjust-a-matic" screw merely causes the freely-mounted pointer shaft to rotate sufficiently to return the pointer to the proper position. Correct recalibration is afforded throughout the dial range. Operation is extremely simple: merely turn the adjustment screw in the direction desired. "Adjust-a-matic" recalibrator is effective up to half of the total dial, or about 90°.—*Certified Gauge and Instrument Corp., 3½-18 Northern Blvd., Long Island City, N. Y.*



Secondary Protector for Current Transformers

A new Thyrite secondary protector, for use on current transformers to provide protection against high open-secondary-circuit voltages, consists of a disk of Thyrite connected across the transformer secondary terminals, together with a thermostatically operated short-circuiting switch. *Operation:* When external secondary circuit becomes accidentally opened, secondary current will pass through the Thyrite disk. When disk temperature reaches approx. 100°C., thermostat operates switch to shortcircuit Thyrite and prevent overheat damage to Thyrite. When disk temperature drops to approx. 80°C., switch opens. These actions are repeated until normal conditions are restored to secondary circuit, at which time the switch will remain open. Since protector is always parallel with transformer secondary winding, a small amount of current will pass through protector under normal operating conditions. This by-passed current is of such small magnitude that error thereby introduced is less than 0.05% at full rated current. New secondary protector can be used on current transformers which operate instruments, meters or relays.—*General Electric Co., Schenecetady, N. Y.*

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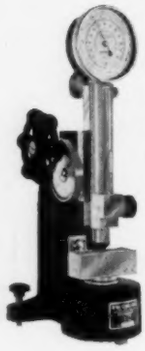

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Wood Moisture Tester

New "Model MB-L Megohm-Bridge" with standard pin-type electrode enables speedy and accurate determination of moisture content in wood by the electrical resistance method. It gives direct readings of moisture-content percent for meeting various specifications of Army, Navy, F.H.A., architects and builders, lumber mills and dealers, furniture manufacturers, railroads, public utilities, etc. Essentially it is a modified Wheatstone Bridge using a cathode-ray (magic eye) electronic tube as the null or balance indicator. The combination switch and control knob is rotated until the null indicator flashes, at which point moisture content is ready directly on the dial. It is said that since the bridge circuit is self-compensating, there are no variables to contend with or compensate for such as voltage fluctuations or varying tube characteristics. The standard pin-type electrode furnished with instrument will not permanently mar surface of material under test; is readily driven into and extracted from lumber or wood by the hammer-extractor furnished. Or, if progressive checks on various lumber stacks are to be made throughout the curing period, leads may be soldered to properly placed and spaced nails, and tied into a panel board located near the instrument for periodic readings. Two models are available: "MB-LA" calibrated 7 to 25% moisture in wood, operating on 105-130-v. 50-60-cycle a.c. supply; portable "Model Megohm Bridge MD-1," calibrated 8 to 24% moisture in wood, operated on self-contained small dry battery with an estimated life of 6 months to one year, depending on use.—*Industrial Instruments, Inc., 156 Culver Ave., Jersey City, N. J.*